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7/25/68

# DYNAMICS OF UNEMPLOYMENT IN DEVELOPING CITIES: AN INDUSTRIAL DYNAMICS STUDY

A THESIS

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Dedicated to my wife, Zoraida

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# CHAPTER I

## INTRODUCTION

Industrial dynamics has been described as the application of the feedback concepts to socioeconomic systems. It represents a totally different approach that, if properly used, can lead to a higher level of understanding of the system under study.

Since it was developed by Professor Forrester in 1960, the industrial dynamics philosophy has provoked many contradictory opinions which have produced much discussion and criticism. However, much of the controversy has arisen because of the different ways people view industrial dynamics. On the one hand, some people consider it a simulation technique; presumably, they assume that industrial dynamics and the DYNAMO-compiler are the same thing. On the other side, Forrester's followers support the idea that industrial dynamics is a developing philosophy which has its own body of theory and, concurrently, its own methodology. In such case, the DYNAMO-compiler is merely the tool used for the simulation runs.

This research deals with the second point of view. Its purpose is the understanding of the philosophy and methodology of an industrial dynamics study.

To accomplish the latter, the system dealing with the unemployment of human resources in developing cities was selected for study. Data and information on the city of Bogota, Colombia, S.A., have been used.

# CHAPTER II

# LITERATURE SURVEY

## Brief Background

### Definitions

Economic writers have discussed in great detail during the last two decades different types of inappropriate utilization of human resources. All have agreed in identifying unemployment and underemployment as the crucial points which affect such lack of efficiency. However, at the present, there is no precise definition which allows a rapid distinction between the two. Simply put, unemployment describes the situation in which a person, who is able to work, is not working; underemployment describes the situation in which worker capacity is not fully engaged (15, p. 58).

In theory, the labor force is composed of persons who are working and all the people who are seeking jobs (3, p. 23). If all people who desire and are able to work find jobs at appropriate normal salaries, the economic system is said to be at full employment (3, p. 23). Unfortunately, the full employment level cannot be reached. Economists support the thesis that a minimum amount of unemployment always will exist, due principally to distortions of the market such as lack of information or available skills which do not coincide with job requirements. Moreover, in any just economic system, the worker must have the freedom to move from one job to another.

Abba Lerner (11, p. 15), in defining the different types of unemployment, states that the general lack of jobs can be called recession by deflation. The situation produced when workers have aptitudes not sought or when they are in a place where those aptitudes are not used is the frictional recession. These definitions have undergone many adaptations when governments and agencies have tried to analyze unemployment in consonance with specific characteristics of a particular country or countries. Among the research regarding unemployment policies for Latin America are two important studies dealing with the unemployment problem in Colombia. The first is the research by the Centro de Estudios sobre Dessarrollo Economico (CEDE) (3) of the Universidad de los Andes in Bogota, published in January 1968. This was the first attempt at a concise and specific work with the objectives of understanding the structure of the unemployment in this country and of identifying the appropriate general policies. The second is a study by Robert L. Slighton (18) of the RAND Corporation (RAND), also published in January 1968. Although the two studies were made separately, both use the same data. The data have been collected by the CEDE since 1963, by using periodic surveys in the most important cities of the country.

Another study related to this topic is the Pearson report (15) of the Commission on International Development submitted to the International Bank for Reconstruction and Development on September 15, 1969.

The International Labor Organization (I.L.O.) is actively working on this problem in developing countries. In recent months (January 12, 1970), the former President of Colombia, Dr. Carlos Lleras (13), installed the mission of the I.L.O. in Bogota; at the present, its preliminary results are being published. Probably CEDE's and RAND's previous research efforts are the basis for this study.

In its work, CEDE uses Lerner's definition, with a slight but important distinction: They decompose Lerner's frictional recess into:

(1) "Frictional unemployment" with short-run effects and due to the lack of information required to match the job supply, and

(2) "Structural unemployment" with long-run effects and due to lack of aptitudes required by the available jobs. This is a discrepancy between the type of job supply and the kind of workers demanded.

CEDE defines an unemployed person as (3, p. 33; 18, p. 3): "An individual of age of fourteen or older who has worked less than 32 hours during the week considered and who was willing and able to work more than 32 hours, roughly 60% of the standard industrial work week of more than 50 hours."

Slighton (18, p. 3) of the RAND Corporation notes that the above definition has two conceptual deficiencies:

(1) It understates the partial employment, and

(2) It ignores the "disguised" unemployment.

By disguised unemployment he means the situation in which a person drops out of the labor force because he is discouraged and believes that he is not going to find a job. However, as the data collected by CEDE are practically the only statistics of this type that exist in Colombia, Slighton adopts in his study their definition for unemployment.

A recent revision of the standard definition used by the U.S. Bureau of Labor Statistics (BLS) was published in Business Week on February 14, 1970. It reads:

> Those who are out of work and say they want a job but have not looked for one in the preceding four weeks--are no longer counted among the unemployed as they once were. People who were not seeking employment because they believed no jobs were available were counted as unemployed; they are now considered out of the labor force.

The Pearson report does not say specifically which definition it uses, although it is expected that it used the BLS one, without the recent modifications.

Structure of Unemployment

Four types of unemployment have been analyzed in the above-mentioned studies:

(1) Lerner -- unemployment by deflation, due to a general lack of jobs,

(2) Structural unemployment (long-run effect) as defined by the CEDE and meaning the market distortion in which workers' aptitudes cannot meet the jobs' requirements,

(3) Frictional unemployment (short-run effect) in which the market is distorted principally because of lack of information, and

(4) Disguised or hidden unemployment in which non-workers decide to leave the labor force because of their discouragement from continuing to seek jobs.

The CEDE research discusses underemployment rather briefly. They suggest two kinds of underemployment:

(1) Visible underemployment, defined as: "All persons which are working in activities of very low productivity and of course with very low remuneration during all or part of their time" (3, p. 31).

(2) Hidden underemployment, formed by all those persons who are working in productive activities part time, but who could and would like to work full time (3, p. 32).

Both the CEDE and RAND studies admit the probable existence of both types of underemployment in Colombia. Specifically, they state that agricultural workers are underemployed because of the relatively low productivity and because they have periods of idleness. Although many economists say that underemployment in developing countries is as dangerous as unemployment, the two studies have been focused on unemployment, mainly because at the present time there is no acceptable, practical way to measure underemployment.

## Measurement of Unemployment

Due to the lack of precise definitions, the measurement of unemployment is a complex problem. Most of the time, the method used is to measure unemployment as a percentage of the labor force (3, p. 32). Since the labor force is composed of (1) workers and (2) persons who actively are looking for jobs, the unemployment rate is calculated by dividing the number of persons seeking work by the labor force. This method has been used in developed countries; however, as the method does not consider underemployment, to use it in developing countries, where underemployment is high, will tend to understate the whole problem. For this reason, economists are constructing a "subemployment" index in order to weight the unemployment rate according to the economic activity analyzed (3, p. 32; 18, p. 4). With this correction, the old unemployment rate indicates whether a person is unemployed or not, and the "subemployment" index indicates the "grade of unemployment (25). The CEDE research suggests as a possible index of weight the ratio of unused labor in man-hours divided by the total used and non-used labor in man-hours. However, they consider that this method, although useful for the rural sector, would not be the most practical in the large cities of Colombia.

One objection to the last method is that it does not count the hidden underemployment (3, p. 34). One possible way to measure it is to determine the personal productivity per individual personal income (3, p. 35). The "subemployment" index method admits three variants (18, p.4):

Criterion A. This is the standard method with subemployment index of one.

Criterion B. "The ratio of the man-hours not worked to man-hours available" (18, p. 4). This criterion assumes that the entire labor force wishes to work a standard work week (48 or 50 hours).

Criterion C. Same as B, but the man-hours available "is the total number of man-hours that the interviewees actually wanted to supply" (18, p. 4).

## Proposed Solutions

### The CEDE Research (3)

The CEDE study presents in its first chapter the basis for an employment policy. This work was carried out by seven researchers, each of whom analyzed the unemployment structure separately, giving special attention to some of the relevant aspects which influence the problem. Although the data and techniques used were the same in all cases, the conclusions are presented separately and only a very general sketch of what could be an employment policy is given.

Some of these conclusions are as follows:

(1) In Colombia the structural unemployment is practically one-half of the total unemployment. This means that the problem might not necessarily be solved with Keynesian policies (i.e., government investment for the creation of new jobs). Probably these policies would only produce an increase in the general price level.

(2) The "disguised" unemployment in Bogota is a relevant factor in the unemployment structure. Thus, it could be expected that the creation of new labor sources would not decrease the unemployment rate, because people outside the labor force would be encouraged to join it.

(3) To attack the problem with orthodox policies, such as the creation of new public works and monetary policies, would not improve the employment level. It is necessary to combine them with others, of the structural type. Some of these would be:

(a) Tax exemptions for industries which develop training programs for their workers.

(b) More investment in education.

(c) Invention and implementation of labor-intensive technologies which would be profitable in economic terms.

(d) Invention and implementation of technologies which would use the actual aptitudes of Colombian workers.

(4) There is a compromise between employment and inflation: The higher the employment level, the higher the price level. The relationship is measured by the "Phillips curve." The research suggests that the curve can be shifted by improving the labor capacity of the poorly trained and by decreasing underemployment (3, p. 29). The same idea appears in (25).

(5) The short-run frictional unemployment is not so important. Consequently, it would not be appropriate to invest large amounts of money in the creation of a government employment agency.

<u>The Slighton Research (18)</u>

The Slighton research is part of a broad study of Colombia being undertaken by the RAND Corporation with funds provided by the U.S. Agency for International Development (A.I.D.) and the RAND Corporation. It must be considered as a preliminary work to the definitive research paper.

Slighton has pointed out that if the rate and pattern of growth of total output does not have a "sharp change," the unemployment situation will become "considerably worse."

> During the 1950's and early 1960's an average annual rate of growth of total output of about 5 percent would have been required to prevent any increase in the unemployment rate. In the next ten years this required rate of growth will be at least 6 percent. If the future rate of growth of output in Colombia is the same as the historic rate of growth, the unemployment rate is likely to double within the next six to seven years.

To make matters worse, it appears that the relationship between unemployment and education is very weak. The unemployment rates are practically the same for skilled people as for unskilled people. This would suggest a lack of sensitivity of the system to an educational stimulus.

He has pointed out that there is no evidence that the large amount of migration from the countryside to the cities has been a cause of the rising unemployment rate. The pros and cons of a labor-intensive public works program must not be discussed until it is known how sensitive the rate of rural-urban migration is to the availability of jobs in the city. Such a program could make the situation worse if it caused a substantial increase in the internal migration rate (18, p. 57).

As general policy changes, he has suggested the following:

(1) The simplest way to reduce unemployment is to increase the aggregate demand and augment the supply of imports.

(2) Creation of policies oriented to limit the further increases in the substitution rate of capital for labor.

His research focused on this point. He understands the problem of "encouraging the substitution of labor for capital in Colombia as being basically the problem of transforming an imported technology." His research analyzes possibilities of augmenting <u>incentives</u> in transforming such imported technology and discusses the possibilities of increasing the local <u>capability</u> to do so.

Among those factors leading to augmenting incentives to increase the substitution rate of capital for labor is the taxation policy. However, in the Colombian case, tax policy probably encourages the substitution of labor for capital. The problem rather is focused on deficiencies of tariffs and import licensing policies (18, p. 58).

Other aspects which probably need a change are those related to the labor code, for example, the terms under which employment can be terminated and those defining relative wage rates for multiple-shift operation or defining job security. This would be a serious handicap in designing production technologies adapted to the situation in Colombia (18, p. 60).

Among those factors dealing with the local ability to reduce the substitution rate of labor for capital appears the lack of willingness of the entrepreneurs to achieve technology adaptation. It seems cheaper to hire foreign technical personnel to adapt a technology which they know than to develop "by themselves" alternative technologies of production (18, p. 62). The cause of such distortion would be the small supply of highly trained managerial and technical personnel and a failure of management to allocate labor resources efficiently (18, p. 64).

The Pearson Report (15)

Pearson et al. (15, p. 58) conclude that unemployment and underutilization of human resources have increased continuously during the 1960's and that the prospects for the next decade are even worse.

They have pointed out as possible causes which could explain the progress of unemployment the following:

(1) Since the population explosion has not had an immediate effect on the labor force rate, population policies will influence unemployment only in the long run.

(2) The overstimulation of capital-intensive and labor-saving policies has improved the competitive efficiency of industry and agriculture but has had very little effect upon unemployment.

(3) Premature mechanization of agriculture in most developing countries does not stimulate the use of labor. Consequently, immigration to the cities has a positive effect on unemployment.

(4) Pressures toward increasing wages have discouraged entrepreneurs from using labor.

Pearson et al. suggest that any appropriate policy must consider corrective actions relative to the above observations. In order to reduce unemployment and underemployment, such a policy would require:

(1) Increased use of unskilled labor to meet the most urgent needs: housing, building of secondary roads, irrigation facilities,

construction of schools, etc. Since this type of program requires large amounts of money, governments must manipulate fiscal policies and foreign aid in order to avoid the inflationary impact of excessive expenditures and the possible shortage of foreign exchange.

(2) That the strategic planning in developing countries stimulate the growth of intermediate rural centers by developing light labor-intensive industries which process local raw materials, as well as services and storage facilities.

## Data, Methodology, and Comparison

The data resources of Colombia are very limited. The less dubious censuses were conducted in 1938, 1951, and 1964 (12). However, all of them used different definitions for the related variables; mainly for this reason, these censuses are not comparable (12).

The Departamento Administrativo Nacional de Estadistica (DANE) has been collecting pertinent information and data in recent years. The same is true for the Centro de Estudios sobre Desarrollo Economico (CEDE) of the University of Los Andes; they have been making surveys related to unemployment since 1963 (3). Slighton has pointed out that CEDE data are, in many cases, quite inconsistent with the DANE unemployment data. He suggests that such inconsistence must be related to the difference in the population sampled.

In the CEDE research, the methodology is a sampled statistic correlation technique (3, p. 307). Criticisms of the sampled procedure are found in Slighton (18, p. 67).

Slighton's research uses the data collected by the CEDE and in some cases the DANE's data. Its methodology is mainly statistical analysis of results based on the input data. However, presumably, he uses some descriptive information from interviews and reports (18, p. iii) as an important aid in making his judgments.

To summarize their approaches in simple terms, it seems that the CEDE research focuses principally on understanding the reason why the unemployed cannot find jobs. The Slighton research concentrates rather on understanding why entrepreneurs cannot or do not want to hire more of them. This difference in emphasis could explain the reason for the apparent opposite directions in their conclusions.

The Pearson report does not say which methodology they used. However, it seems that statistical analysis also was used.

# CHAPTER III

# OBJECTIVES AND APPROACH

## Purpose and Objectives

The purpose of the present research is to further the understanding of industrial dynamics philosophy. Its objectives are threefold:

(1) To understand the character and structure of the information feedback loops which exist in any socioeconomic system.

(2) To understand why those information feedback loops cause the patterns of behavior of any system.

(3) To learn the methodology needed to develop an industrial dynamics study.

The problem selected for simulation deals with unemployment behavior in developing cities. However, the present research does not pretend to offer possible solutions to that problem.

## Scope

Data, general information, and actual conditions used in the model were taken from Bogota, Colombia, S.A. (3, 12, 14, 16, 18, 19, 20). This is a developing city which offers good possibilities for experimentation. Bogota has one of the highest rates of population increase in the world (3, p. 124; 14, p. 19) and very high unemployment and inmigration rates (3, p. 109). Bogota's traditional social structure is now in the process of being modified. The receptive attitudes of people toward innovation and change have been, in recent years, the reasons for seeking new social patterns and structures. The situation outlined above makes Bogota especially attractive to study from the point of view of industrial dynamics.

## Methodology

The following methodology is inherent to industrial dynamics (5, p. 13).

(1) Description of the problem. Selection of the possible patterns of behavior of the main variables dealing with the problem.

(2) Identification of the main factors to be included. Determination of the boundaries of the system.

(3) Identification of the information feedback loops which cause the patterns of behavior.

(4) Construction of a mathematical model representing the interaction between variables.

(5) Generation of the behavior of the model through time.

(6) Comparison of actual patterns with the ones assumed in point (1).

(7) Revision and/or redesign of the model until it is an acceptable representation of the real system.

(8) Selection of appropriate targets for improvement.

(9) Redesigning of policies in such a way that they improve the model's behavior toward the target selected in point (8).

This research deals with points (1) through (6).

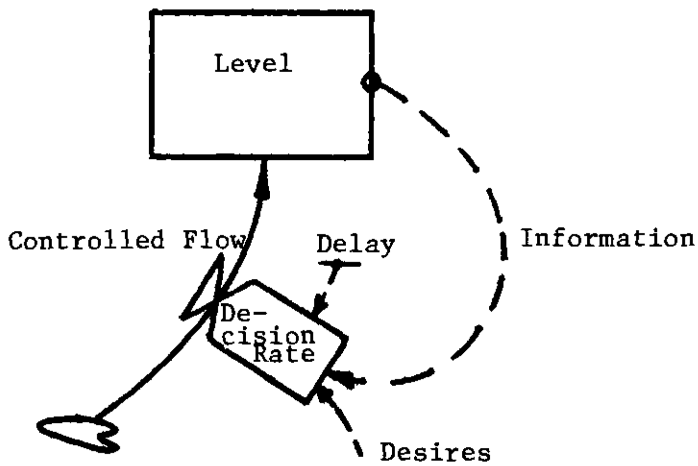
## Assumptions

Recognition of the existence of closed feedback loops in any socioeconomic system is one of the corner-stones of the industrial dynamics approach. Professor Forrester says: "An information feedback system exists whenever the environment leads to a decision that results in action which affects the environment and thereby influences future decisions." (5, p. 14)

The second crucial assumption concerns the character of the process of decision-making.

> Decisions fundamentally involve three things. First is the creation of a concept of a desired apparent state of actual conditions. The third part of the decision process is the generation of the kinds of actions that will be taken in accordance with any discrepancy which can be detected between the apparent and the desired conditions (5, p. 17).

The diagram below represents the simplest possible information feedback loop.




Information feedback loops are always composed of accumulations (called levels), flow rates, and information. Flow rates cause accumulations to vary with time; accumulations, in turn, affect the information network entering into the decision process, which controls the flow rate. Finally, changes in the value of flow rates produce new changes in accumulations. This fact closes the loop. The above changes in flow rates and accumulations are not produced instantaneously. Inherent delays exist between the time the action is taken and the time the response is observed. These delays appear at all decision points, and may also exist in some information networks.

Information feedback loops can be of two types: negative or positive. When an increasing (decreasing) level leads to a varying flow rate which makes the level increase (decrease) even more, the feedback loop is positive. On the other hand, if an increasing (decreasing) level leads to a varying flow rate which makes the level decrease (increase), the feedback loop is negative. Finally, the positive feedback is related to any growth process, while the negative one is related to goal-seeking systems.

# CHAPTER IV

## DESCRIPTION OF THE PROBLEM

The first step in an industrial dynamics study is the description of the possible causes which have created the problem, as well as the selection of the appropriate patterns of behavior which presumably represent the kind of situation under study.

The underutilization of human resources has been increasing in Colombia since 1960, and the prospects for the immediate future look even worse if appropriate corrective policies are not implemented.

Economists have suggested the following possible causes of the high unemployment rate in the largest city of Colombia (i.e., Bogota):

(1) The demand for goods has not kept up with increases in production. This eventually leads to an overaccumulation of inventories which discourages investments (18).

(2) The rate of substitution of capital-intensive techniques for labor is increasing (18, 3).

(3) The level of investment in education is very low, fostering a high structural unemployment (3).

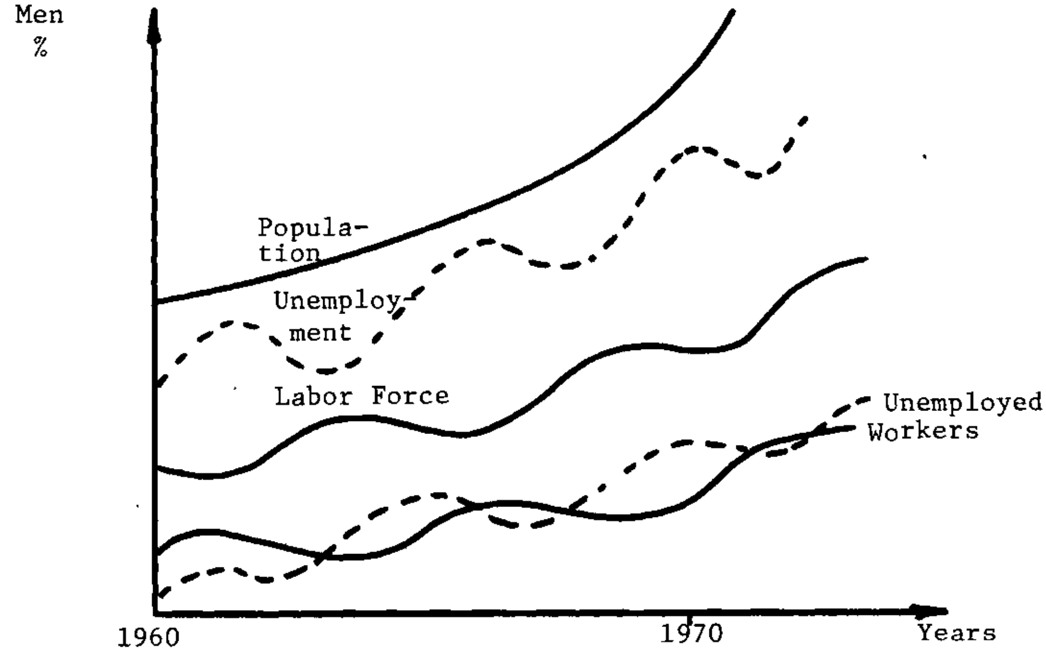
(4) Population growth (six per cent in Bogota, 1970) influences unemployment in the long run (3, 15).

(5) The salary difference between the rural sector and the city, as well as the premature mechanization of agriculture, has brought about an increasing rate of migration to the city (3, 15).

This research assumes points 1, 2, and 4 to be the most relevant aspects dealing with the high unemployment pattern of Bogota. It does not consider points 3 and 5.

The following patterns of behavior are assumed to be the ones which have existed in Bogota since 1960. These patterns are supported by the literature survey, and they represent the description of the problem.

The model to be built must behave in a similar way. If the behavior of the model is different, we must conclude that it does not represent the actual system. However, if it behaves according to the above hypothesis, we cannot immediately conclude that the model is an adequate representation of the real system. Also necessary are subjective beliefs that the facts shown in the model represent the most crucial factors related to the unemployment in developing cities (5, p. 123).



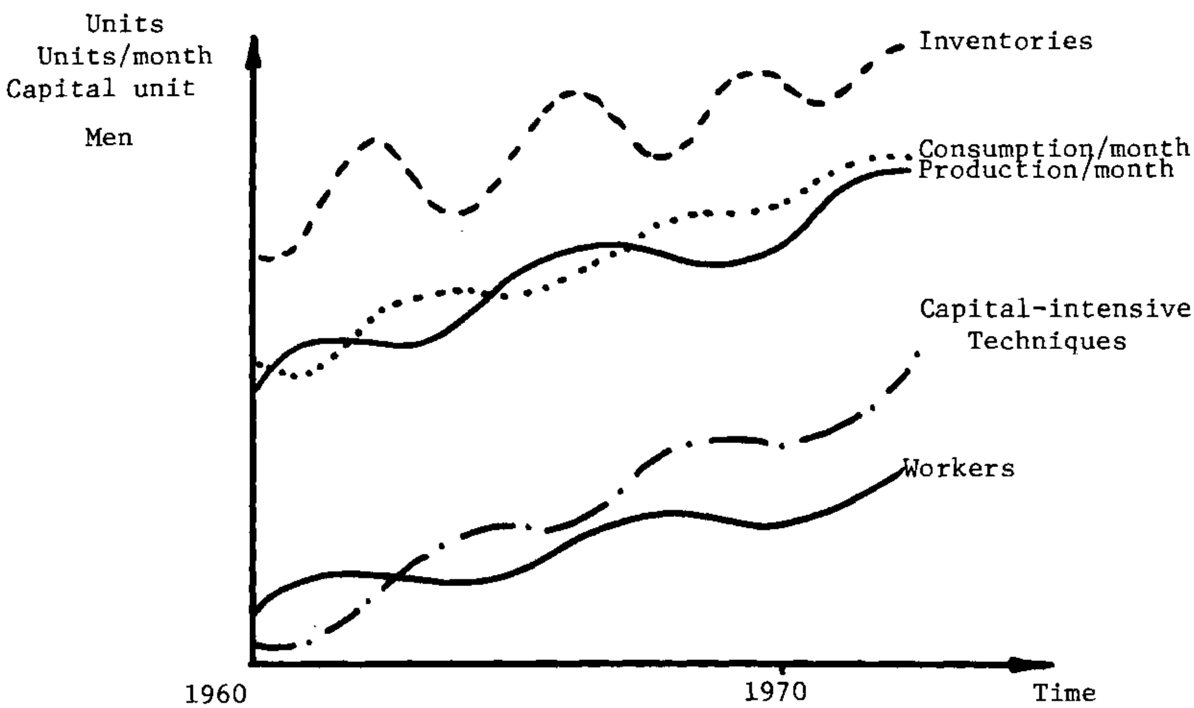




Fig. 1. Hypothesis of Behavior

# CHAPTER V

# THE MODEL

## Structure of the Unemployment Model

### Major System Sector

The second step in exploring the behavior of an industrial dynamics model is to design a general system containing those major sectors which seem to be significant for an appropriate representation of the characteristics and behavior of the system. The general system proposed must be as simple and basic as possible, but should allow for (1) the definition of the boundaries of the system (2) the selection of the most relevant factors, and (3) the identification of the feedback loops which determine the proposed behavior of the system. To accomplish the third task is probably the most important step in building industrial dynamics models; at the same time, it is one of the most difficult parts of the process.

### Selected Sectors to Be Included and Their Boundaries

The general system proposed is shown in Figure 2. Four main sectors, the unemployed sector, the aggregate production of goods and services sector, the capital-intensive sector, and the consumer sector, must have those mutual interactions which will recreate the patterns dealing with the unemployment situation in the city. The double arrows between the unemployed sector and the aggregate production sector represent the flow of people going from one sector to the other. People already in the latter sector represent not only the level of workers in the city, but also potential consumers in the consumer sector.

The unemployed sector represents the following types of unemployment: the frictional, the structural, and the Lerner unemployment by deflation; however, it does not consider hidden unemployment or the underemployment situation. These are two of the limitations of the present research.

The aggregate production sector contains the workers, the active capital-intensive equipment (in use), and the aggregate of goods and services being produced by industries and government. Between this sector and the unemployed sector, there are also information links representing the actual knowledge (not always the true knowledge) of entrepreneurs, managers, workers, and unemployed about the state of the system. Forming these information links are all the massive and direct ways of communication, such as personal conversations; telephone, radio, and television; and the sophisticated computers; the above information links come from the state of the system and form the channels entering into the decisions, affecting them and governing their flows. These flows, in turn, produce changes in the state of the system, thus creating an information feedback and producing a pattern of behavior.

The capital-intensive sector and the consumer sector also interact with the aggregate production sector. By capital-intensive sector is meant all kinds of equipment and techniques which it is feasible to obtain within a reasonable period of time and with the economic resources of the city. As they represent a labor-saving factor to entrepreneurs, they will be called labor-saving techniques from now on.

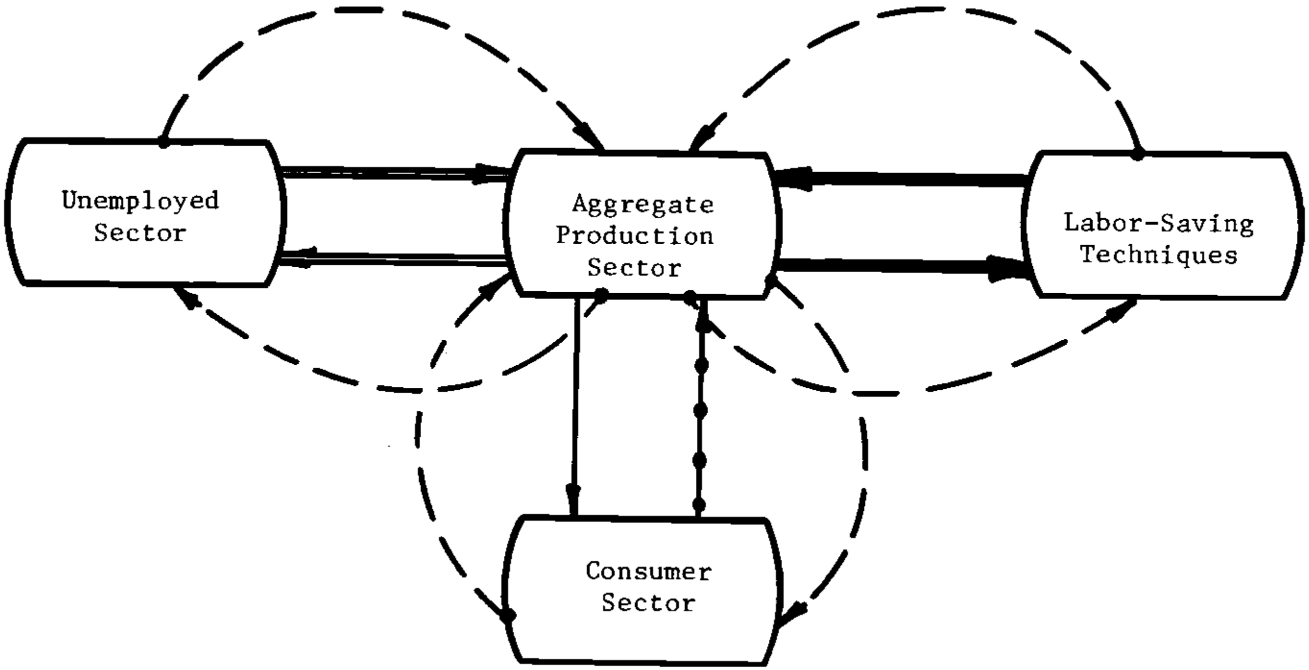



Figure 2. Major System Sectors

The consumer sector is formed not only by the workers (and their salaries), but also by the government and other enterprises consuming intermediate goods. However, it will be assumed in the model that the set workers' salaries can provide an adequate measure of the total potential consumption of finished and intermediate goods and services if the model includes the multiplier consumption effect and some appropriate delays. Between this sector and the aggregate production sector there are a flow of orders, a flow of goods and services, and also the information links forming the information feedback loops.

Within the information network relating the unemployed sector, the aggregate production sector, and the consumer sector, two secondary but important sectors can be considered (Figure 3). One is the salary sector, and the other is a subsystem representing the "confidences" of people and entrepreneurs in the system. These two sectors also interact and form additional information feedback loops.

The above selected sectors also define the boundaries of the system (Figure 3). Those variables not receiving effects from factors which are part of the model are outside the system and determine the boundaries of the system. They are the inputs of the system and must not be crucial factors affecting the behavior of the model; if so, they must be included in the model as belonging to at least an information feedback loop.

This model assumes the population pattern of the city and the price level as two independent inputs to the model. Whereas, the population pattern seems to be influenced very little by variables inside the model, the same seems not to be true for the price level. Although changes in price level can have a definite influence upon the consumption,

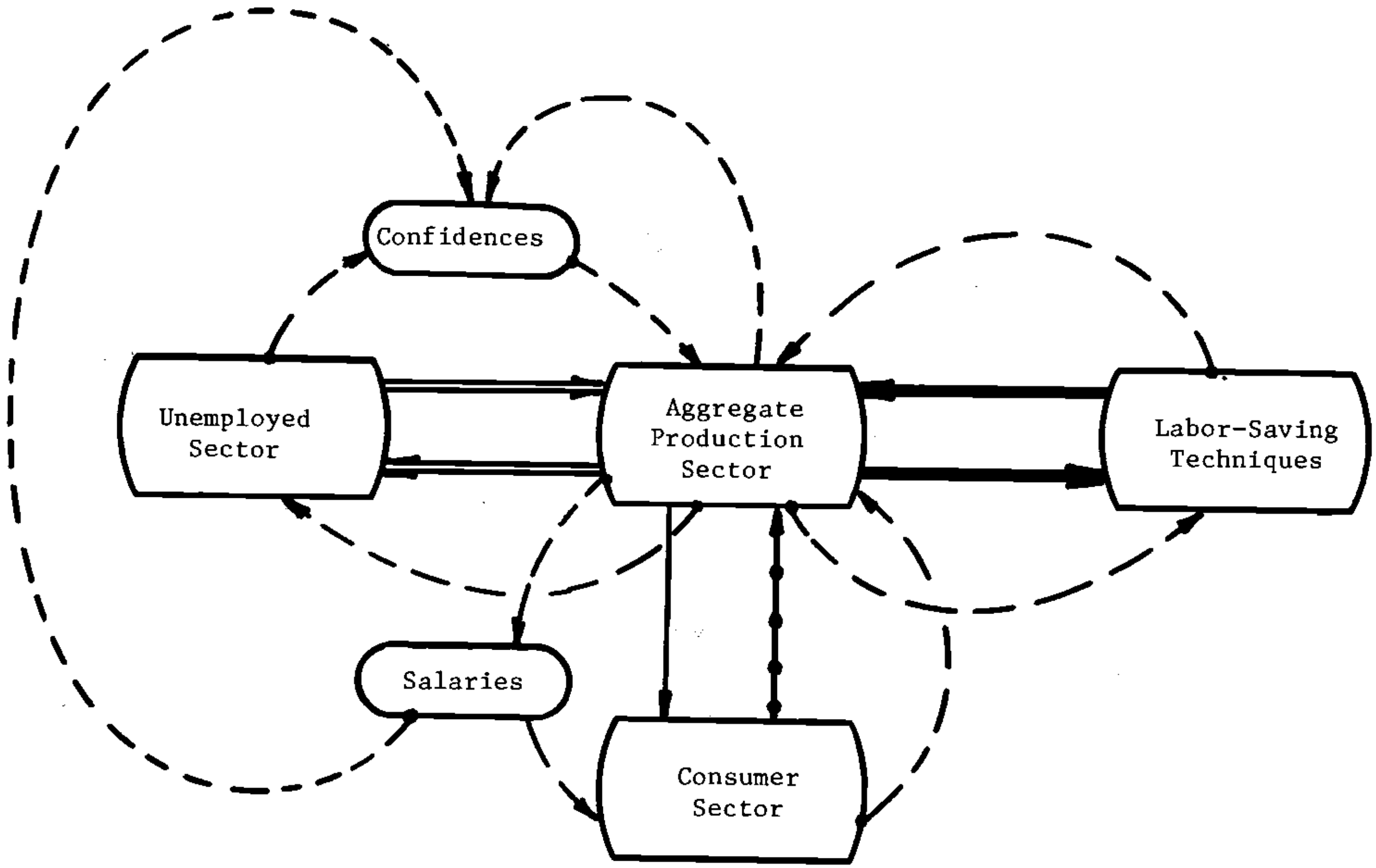



Figure 3. The Five Sectors of the System

upon the acquisition of equipment, and upon the confidence of the public, it is unrealistic to think that changes in the production level and unemployment will not influence the price level as well. Thus, the price level would seem to belong to at least an information feedback loop and, consequently, it would be within the system. However, there are also other factors which affect the price level. Among these, the monetary and fiscal policies of government and international trade are not in any way less important than the unemployment level and the production level. Furthermore, when attempting to find the real chains of causes and effects related to the price level, it is very difficult to determine if one of the above influencing factors is really a cause of the price level changes, or if it is only a correlated factor. This could be the case of the Phillips curve (price level vs. unemployment) that has been observed in many countries. Is unemployment really one of the causes for the varying price level, or rather does there exist a correlated effect brought about by a third cause? Industrial dynamics philosophy requires that the information feedback loops include chains of causes and effects, not correlated effects. As the proposed model does not consider monetary and fiscal policies and international (or intercity) trade, it seems to be preferable for this simplified model to incorporate the price level as an input variable.

Nevertheless, it is possible to obtain some knowledge by treating the price level as an input variable. If the model to be set up is not very sensitive to changes in the price level, we can conclude that probably some important characteristics of the system are misleading. However, the sensitivity of the price level is not a guarantee that the model includes the most appropriate facts. (The condition is necessary, but not sufficient.)

Finally, the model assumes that entrepreneurs can finance their investment projects.

Identification of the Information Feedback Loops Which Create the Patterns

The information feedback loops which presumably are going to be the cause of the observed behavior of the actual system are shown in Figure 4. Each arrow indicates that the factor represented at its orign is a cause for the factor represented at its end; it also is assumed that there is a delay between the time a cause is produced and the time it creates the effect. As we shall see later, some of these feedbacks are negative, others are positive. Negative feedbacks represent subsystems seeking and striving for a goal, whereas positive feedbacks represent growing processes. When a negative feedback contains more than two levels (accumulations), the pattern caused can start in oscillations around the desired goal, which obviously can be a varying goal. The interactions of those feedbacks must create the symptoms and the behavior of the unemployment sector.

The main feedbacks of the system are those related to the hiring or firing rate. Some of them are analyzed in the figure below, which represents four positive feedback loops. The sign at the end of the arrows indicates the kind of effect the preceding factor has over the following factor. An increase in the number of workers (production workers) causes an increase in the consumption capacity because it results in more people

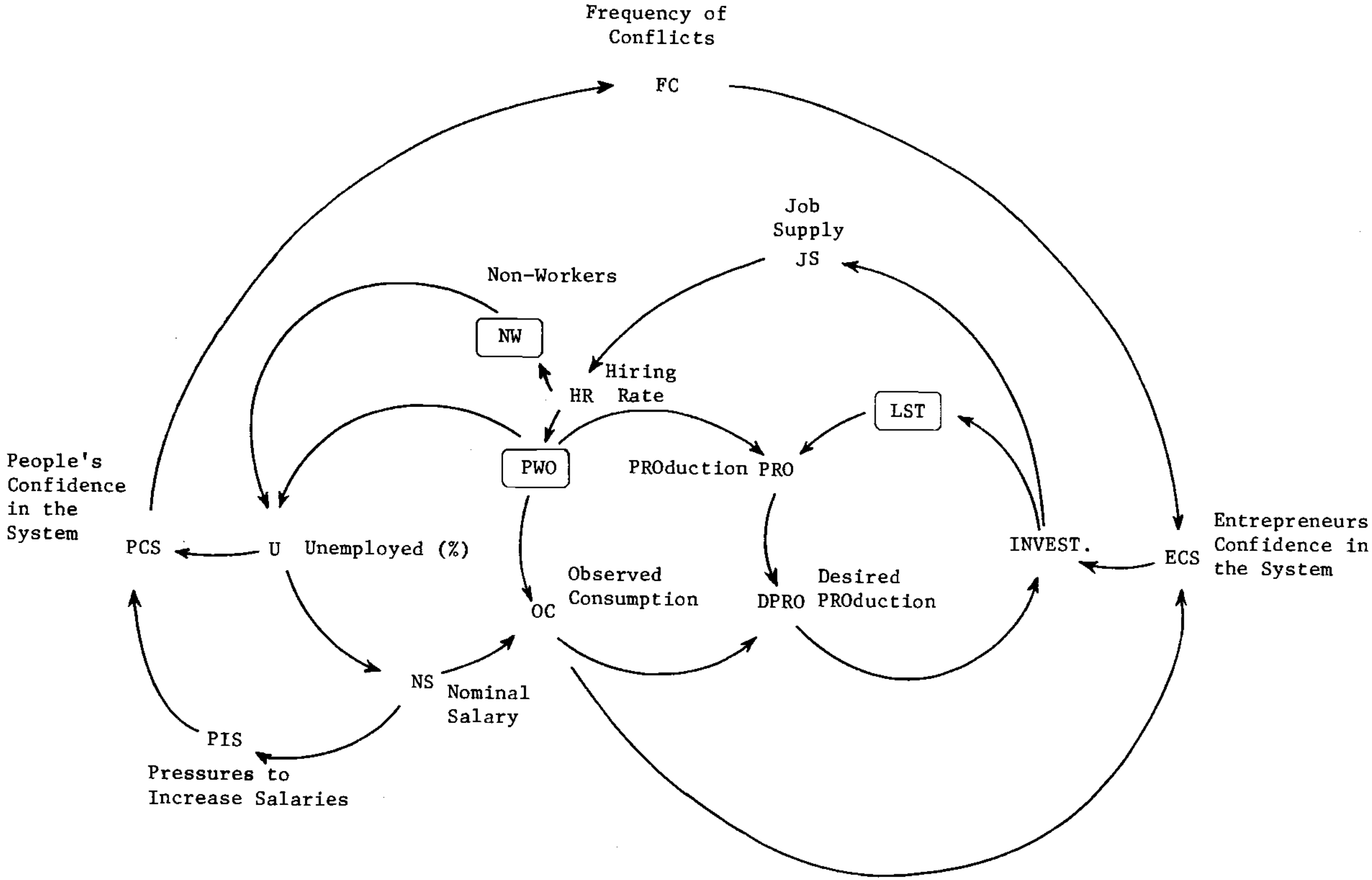



Fig. 4. Main Feedbacks in the System

with more money. The increased consumption capacity makes people consume more, which increases the entrepreneur's desire to produce more. Consequently, he invests more; this, in turn, causes a further increase in the supply of jobs, which results in an increased hiring rate to obtain additional production workers. The process contains delays associated with all the arrows. These delays are very important factors in the feedbacks and must not be missed. The following sections of this chapter will analyze them in some detail.

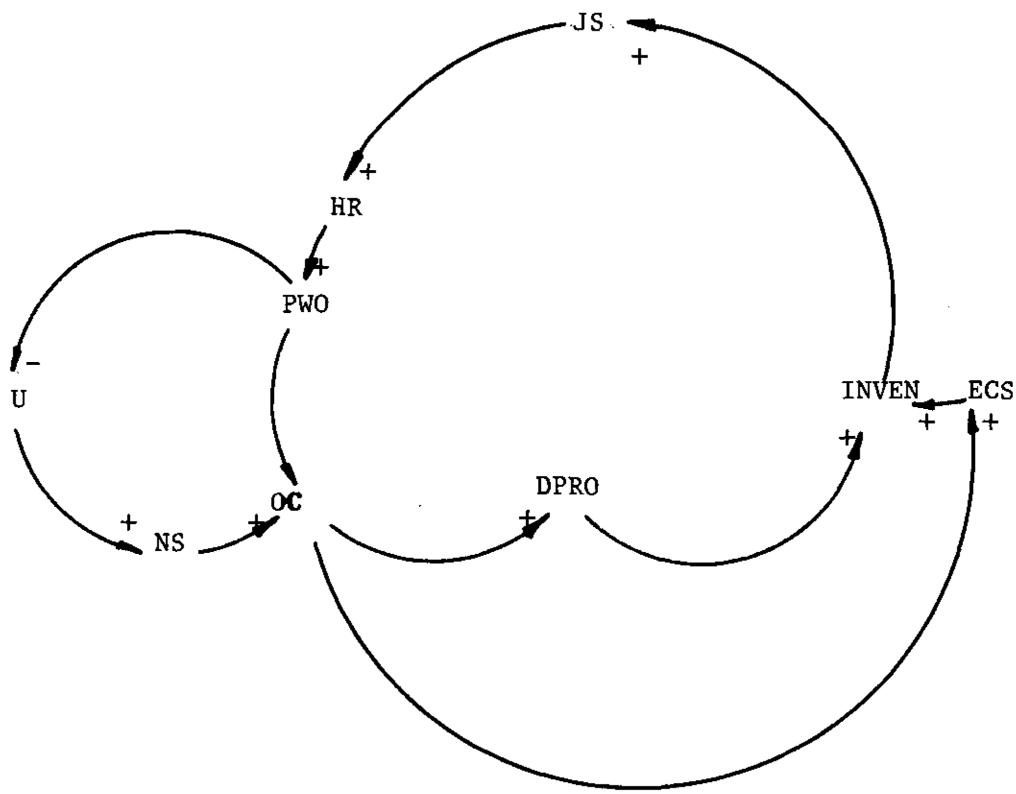



Fig. 5. Four Positive Feedback Loops

The next loop (Figure 5) is coupled with the previous one. After the consumption capacity has increased, entrepreneurs experience a new feeling of confidence which stimulates them to plan for the coming months and concurrently, to find funds for investment which, in turn, will cause increases in the job supply, hiring rate, and finally in the number of production workers.

The third and fourth feedbacks are related to unemployment and salaries. An increase in production workers has a negative effect upon unemployment. (This does not necessarily mean that unemployment decreases, but rather, that its rate of change in relation to production workers is increasing.) This, in turn, probably causes the average salary to increase, mainly for two reasons: first, more people working means less availability of skilled or semiskilled people in a developing city with high structural unemployment; second, an increase in the number of employed persons feeds the unions, which then feel themselves in a stronger position than before, and eventually will force a quicker improvement in wages than would otherwise be the case. A salary increase has a positive effect upon the consumption capacity (being the price level constant). This factor produces positive effects on the two starting paths common to the first and second loop, respectively.

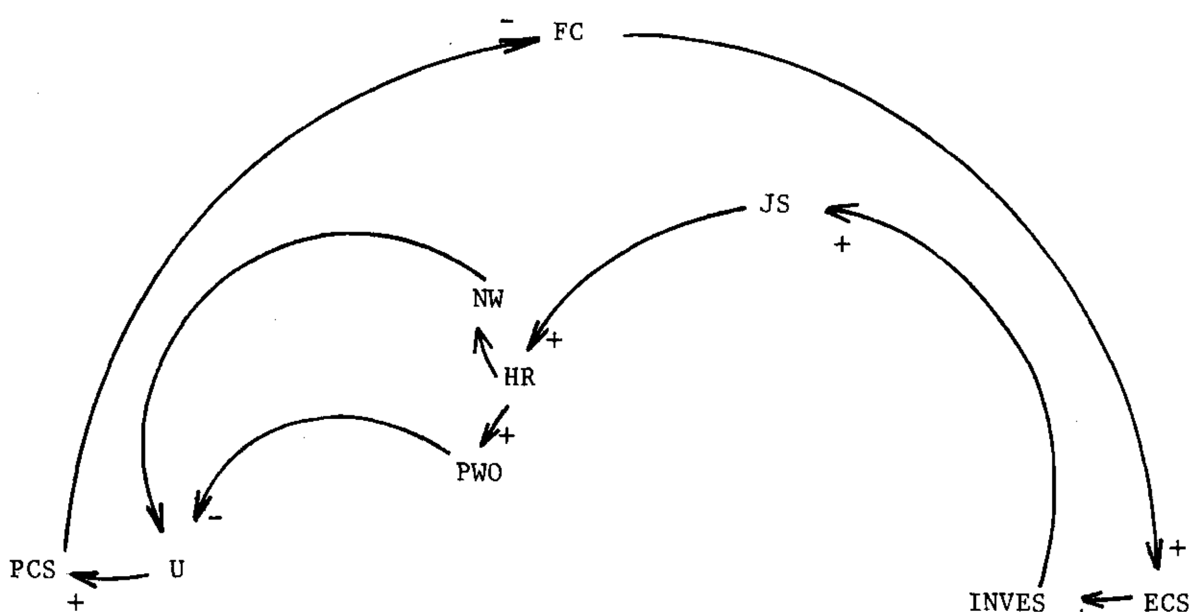



Fig. 6. Two Positive Feedback Loops

The above two feedback loops are also positive. When the number of production workers increases, the effect upon unemployment is negative; the unemployment level rises less rapidly and eventually decreases. This effect improves the people's confidence, thus diminishing the frequency of conflicts (those conflicts caused by unemployed workers, such as violence) and improving the entrepreneur's confidence in the feasibility of new investments. More investments, moreover, cause the job supply to increase further, resulting in a chain reaction of additional hiring and another gain in the number of production workers (Figure 6).

A similar description holds for the second feedback, in which nonworkers represent the unemployed people (Figure 6).

The next types of information feedbacks deal with the production sector (Figure 7).

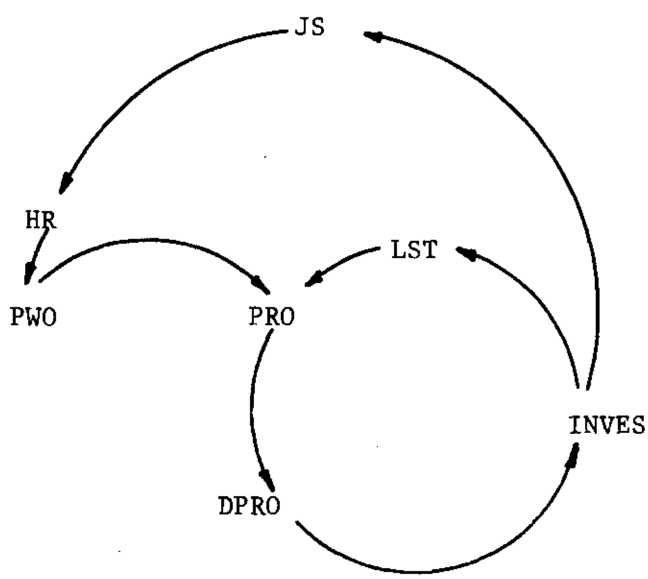



Fig. 7. Two Negative Feedbacks

The figure above represents two negative feedbacks. When the number of production workers (or labor-saving techniques) is expanded, production increases in such a manner that for the time being entrepreneurs do not need to consider further expansions. This lessens the entrepreneurs' desire for more production, and they will try to diminish their investment in both labor-saving techniques (equipment) and job supply. The end result is a decrease in the levels of production workers and labor-saving techniques.

The above descriptions represent the main feedbacks which create the patterns. In the next pages are described additional feedbacks related and coupled with them. Further explanation of all variables, parameters, and delays will appear in the following section.

## Equations Describing the System

For the purpose of making it easier to describe the equations that follow, the subsystem sectors selected will be rearranged as follows:

(1) Labor Sector (unemployed sector and workers)

(2) Salary Sector

(3) Production and Consumption Sector (inventories, production and consumption rates, and backlog)

(4) Labor-Saving Techniques Sector (those in use and prospective ones)

(5) People's and Entrepreneurs' Confidence Sector

### Labor Sector

The labor sector represents the labor force and its structural changes which are due to the varying job supply. Structural changes within the labor force influence the number of employed and unemployed people in the system, and provide new changes in other sectors of the system; these, in turn, will affect the job supply and will produce new changes in the labor force structure.

The labor force and its governing policies are represented in Figure 8. The flow of people forms a close loop which contains three levels: a level of non-working people ready to start working if they had such a prospect, a level of people receiving some kind of training; and a level of production workers. This model assumes the following process: When a non-worker is hired, he enters into an initial training state in which he is trained for some period of time, following which, he proceeds into a level of production workers. People on this level represent the actual manpower of the city. During periods of time in which entrepreneurs decide to fire people, workers are forced to come back to the labor pool of non-workers.

As the city expands and its population rate and migration rate increase, we can expect new people to enter into the labor pool. We shall call this flow of new people labor force rate; and it has the effect of increasing the non-working level.

Under these circumstances, the non-worker level is affected by three rates: a labor force rate, a hiring rate, and a firing rate. Its equation will be:

$$NW.K = NW.J + (DT)(LFR.JK - HR.JK + FR.JK + 0) \qquad (1L)$$

| | |
|---|---|
| NW | Non-Workers (men) |
| LFR | Labor Force Rate (men/month) |
| HR | Hiring Rate (men/month) |
| FR | Firing Rate (men/month) |

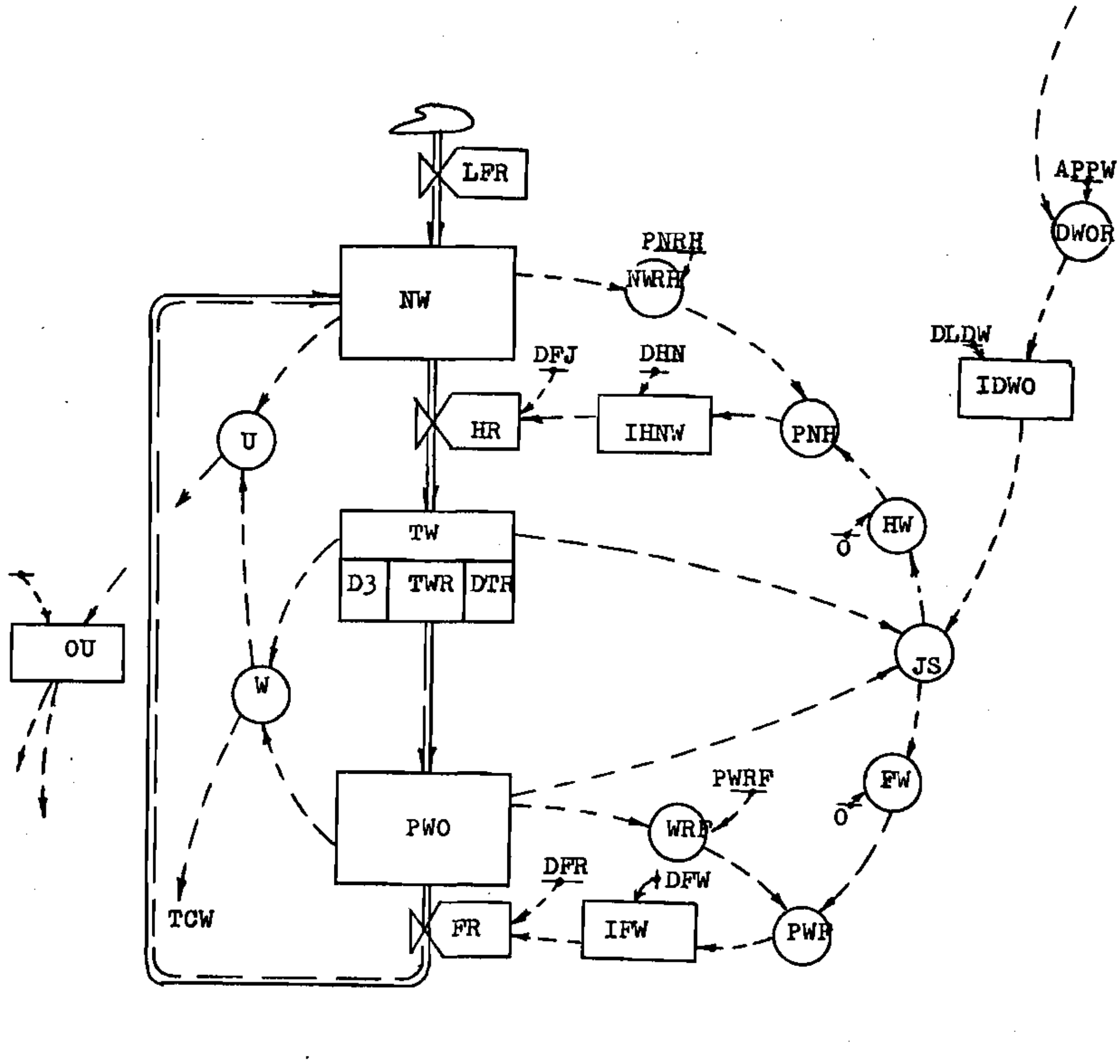



Fig. 8. Labor Sector

DT    Time interval between solution of the equation (months)

0    Zero, in order to fit DYNAMO equation

The equation says that the level of non-workers at the present time, K, is equal to the level of non-workers at the previous time, J, plus the net flow of people during the period of time, JK. (JK is determined by DT.)

The level of people undergoing training is related to the hiring rate and depends upon an outgoing rate which indicates the actual flow of people just finishing the training period and entering into the production worker level.

$$TW.K = TW.J + (DT)(HR.JK - TWR.JK) \qquad (2L)$$

TW    Training Workers (men)

HR    Hiring Rate (men/month)

TWR    Training Workers Rate (men/month)

This level of trainees has a quite special meaning: first, there is a period of time between the time a person without any experience at all is hired and the time he becomes productive. Moreover, if the worker being hired has had previous experience, we can also expect that he will not become fully productive for some period of time, because he probably needs time to acquire the confidence and knowledge required by a new kind of job or by the same kind of job, but under a different environment. Second, although it can be argued that in many industrial situations the new worker begins working without any previous training, it seems likely that in addition to his not being in full production, some production workers must take time to train him, causing a lowering in the effectiveness of workers already producing. For the above two reasons, there is a delay between the time a man is hired for production and the time he actually begins producing.

In an aggregate economy, not all training periods start and finish at the same time, nor do all trainees within the same factory start and finish their training periods simultaneously. This means that the actual period of time a worker is in the training delay will vary according to the type of job and the man's abilities. However, in the aggregate economy, we can reasonably expect an average period of time in which entrepreneurs expect the trainee to acquire the abilities required. Once this average period of training is ended, the entrepreneur allows the trainee to go into the production worker level. The number of men per month allowed to go into the production worker level will receive the name of training workers rate; its related equation is:

TWR.KL = DELAY 3(HR.JK,DTR) (3R)

| | |
|---|---|
| TWR | Training Workers Rate (men/month) |
| HR | Hiring Rate (men/month) |
| DTR | Delay for TRaining workers (average months) |

There are other considerations dealing with this delay. Suppose that the hiring rate has the pattern shown in Figure 9. As the hiring rate starts increasing, we can expect an increase in the training workers level, and obviously the training workers rate also will increase. However, only after some period of time does this rate reach the same value

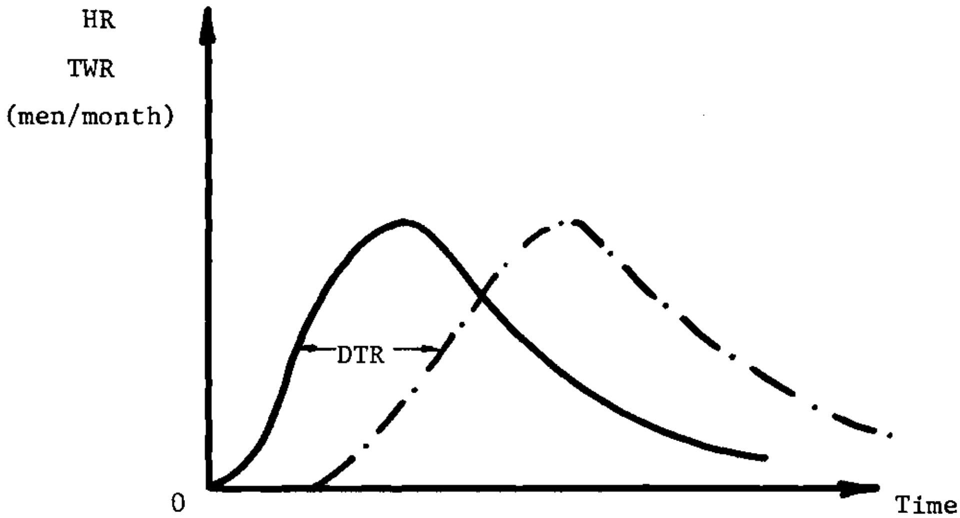



Fig. 9. Effect of a DELAY 3

as the hiring rate. This is the average period of time required to train the new workers. One of the functions which match with the above description is the third-order exponential delay of the DYNAMO compiler.

The production workers level represents the number of people actually producing in the economy of the city. Two rates affect the level: an incoming rate from the training workers level and an outgoing rate or firing rate. The next equation describes the level:

$$PWO.K = PWO.J + (DT)(TWR.JK - FR.JK) \quad (4L)$$

| | |
|---|---|
| PWO | Production WOrkers Rate (men) |
| TWR | Training Workers Rate (men/month) |
| FR | Firing Rate (men/month) |

The hiring and firing rates depend on two factors: one is the entrepreneur's information about the actual level of workers in the system; the other is the entrepreneur's desires for more or less workers in the enterprise. The greater their desires, the more the chances to hire people, and similarly, the higher the actual level of workers, the more the chances to fire people.

It is necessary to define some auxiliary concepts (auxiliary equations) before defining the hiring and firing rates. Auxiliary concepts are used only with the purpose of making clear those concepts entering into the rate equations. In fact, they belong to the rate concepts. However, as they have a real meaning for the decision maker, it is worthwhile not to incorporate them directly into the rate equations. Moreover, as the DYNAMO compiler used in this model does not have all the equation forms required, it is necessary at times to break the equations into two or three separate ones for equation-fitting purposes.

The next auxiliary equation describes the total level of workers within the system:

$$W.K = PWO.K + TW.K \tag{5A}$$

| | |
|---|---|
| W | total level of Workers (men) |
| PWO | Production WOrkers (men) |
| TW | Training Workers (men) |

The desired level of workers will be related to the desired production of those workers and the individual productivity per man:

$$DWOR.K = \frac{DPRW.K}{APPW} \tag{6A}$$

| | |
|---|---|
| DWOR | Desired number of WORkers (men) |
| DPRW | Desired PRoduction of Workers (units/month) |
| APPW | Average Production Per Worker (units/month/men) |

This value does not affect directly the entrepreneur's decision to hire or fire. Rather, this value affects past desires of entrepreneurs for workers and will influence changes in the actual number of people desired. Even more, its impact upon his desires is delayed, for it takes time for the entrepreneur to adjust his convictions to the new situation. A delay smoothing equation fits this description:

$$\text{IDWO.K} = \text{IDWO.J} + (\text{DT}) \frac{1}{\text{DLDW}} (\text{DWOR.J} - \text{IDWO.J}) \qquad (7L)$$

| | |
|---|---|
| IDWO | Indicated Desires for new WOrkers (men) |
| DWOR | Desired number of WORkers (men) |
| DLDW | DeLay for Desired Workers (time to adjust to new conditions) (months) |

The actual number of new jobs will be the difference between the indicated desire for workers and the total level of workers:

$$\text{JS.K} = \text{IDWO.K} - \text{W.K} \qquad (8A)$$

| | |
|---|---|
| JS | Job Supply (jobs = men) |
| IDWO | Indicated Desires for WOrkers (men) |
| W | total level of Workers (men) |

The above equation can hold under two situations: $JS \geq 0$ or $JS < 0$. Under the first situation, entrepreneurs decide to hire more people in the coming months. Under the second, they decide to fire more people during the next few months. The two different situations can be stated as follows:

$$HW.K = MAX(0, JS.K) \tag{9A}$$

$$FW.K = MAX(0, -JS.K) \tag{10A}$$

| | |
|---|---|
| HW | Hiring Workers in the future (men) |
| FW | Firing Workers in the future (men) |
| JS | Job Supply (men) |

It must be observed that when JS > 0, FW = 0 (or JS < 0, HW = 0). This means that when the entrepreneur desires additional workers, he does not intend to fire workers in the future, although he actually can be firing some of them.

Now suppose that the entrepreneur intends to hire more people. Under some circumstances, it can be difficult for him to find all the people required for the type of job offered. In other words, there are insufficient people available for filling the jobs or there are very few people with the required abilities and aptitudes who are seeking those jobs. At least three reasons can account for this situation: (1) the city has a high percentage of structural unemployment (p. 5); (2) entrepreneurs are not willing to hire and to train people with a very low productivity; and (3) the city has a frictional unemployment higher than the normal which probably is due to a lack of information about new opportunities. We shall assume here that all three factors have the influence of limiting the number of new hired people, and that the maximum number of people available for employment is a percentage of the non-worker level:

$$NWRH.K = (PNRH)(NW.K) \tag{11A}$$

NWRH Non-Workers Ready to be Hired (men)

PNRH Percentage of Non-workers Ready to be Hired (dimensionless)

NW Non-Workers (men)

$$PHN.K = MIN(HW.K, NWRH.K) \tag{12A}$$

PHN Potential Number of Hired (men)

HW Hiring Workers in the future (men)

NWRH Non-Workers Ready to be Hired (men)

There is a delay between the time entrepreneurs decide to hire more people and the time they actually offer the new jobs. The reason is that they probably would like to have new space, new facilities, and new programs for the coming workers before they are hired. All these factors together delay the time when the number of hired people reaches its potential. Even more, during this period of time, managers can, in fact, change their intentions and decide to hire more or fewer people in accordance with their new perceptions of the system. A delay-smoothing equation fits this description:

$$IHNW.K = IHNW.J + (DT)\ \frac{1}{DHN}\ (PNH.J - IHNW.J) \tag{13L}$$

IHNW Intended number of Hired Non-Workers (men)

DHN Delay in Hiring Non-workers (months)

PNH Potential Number of Hired (men)

The hiring rate depends directly upon the intended number of hired non-workers. However, it also is delayed, for two reasons: (1) after entrepreneurs make the decision to hire a number of non-workers, they expend time looking for the most suitable men (advertising, meetings, etc.), and (2) there exists a period of time between the time a man is selected and the time he starts working.

$$HR.KL = \frac{IHNW.K}{DFJ} \qquad (14R)$$

| | |
|---|---|
| HR | Hiring Rate (men/month) |
| IHNW | Intended number of Hired Non-Workers (men) |
| DFJ | Delay in Filling Jobs (months) |

There exists an important difference between the delay for hiring non-workers (DHN) and the delay in filling jobs (DFJ). The first is due to delays on the managerial side when offering the jobs; the second is due mainly to a lack of information on the part of non-workers about the kind of jobs being offered.

The feedbacks defining the firing sector are similar in appearance to those defining the hiring sector. However, as we shall see, some of the concepts are different. When entrepreneurs perceive how many workers to fire (FW), they observe whether this value is greater or smaller than the maximum amount of workers available to fire. They will fire the number corresponding to the lower of those values. In other words, although entrepreneurs would begin by firing those workers with the lowest productivity, they would not permit firing more than a certain number of their best men. This idea assumes that during periods of recession, even the entrepreneur has the hope that after a period of time, the business level will again recover its normal state of affairs.

$$WRF.K = (PWRF)(PWO.K) \tag{15A}$$

| | |
|---|---|
| WRF | maximum number of Workers Ready to be Fired (men) |
| PWRF | maximum Percentage of Workers Ready to be Fired (dimensionless) |
| PWO | Production WOrkers (men) |

$$PWF.K = MIN(FW.K,\ WRF.K) \tag{16A}$$

| | |
|---|---|
| PWF | Potential number of Workers to be Fired (men) |
| FW | Firing Workers in the future (men) |
| WRF | maximum number of Workers Ready to be Fired (men) |

In all business situations, there is a period of time between the time the entrepreneur decides how many to fire and which workers to fire, and the time the selected workers receive the dismissal notices. During this period of time, the manager can even change his intentions and decide to fire a larger or smaller number of people according to his new perception of the system. This description holds in a delay-smoothing equation, which defines the intended number of new workers to fire:

$$IFW.K = IFW.J + (DT)\ \frac{1}{DFW}\ (PWF.J - IFW.J) \tag{17L}$$

| | |
|---|---|
| IFW | Intended Workers to Fire (men) |
| DFW | Delay for Firing Workers (months) |
| PWF | Potential number of Workers to Fire (men) |

An additional delay exists between the time a worker receives the dismissal notice and the time he actually leaves the enterprise. This is due mainly to special regulations between governments, unions, and enterprises; for example, in many situations the dismissal notice must be sent one or two months before the worker is actually fired. Then, the firing rate will be a fraction of the intended workers to fire:

$$FR.KL = \frac{IFW.K}{DFR} \qquad (18R)$$

| | |
|---|---|
| FR | Firing Rate (men/month) |
| IFW | Intended Workers to Fire (men) |
| DFR | Delay in FiRing workers (months) |

The last equation of the labor sector will be the unemployment percentage. This research will consider unemployment as a percentage of the labor force:

$$U.K = \frac{NW.K}{NW.K + TW.K + PWO.K} \qquad (19A)$$

| | |
|---|---|
| U | Unemployment (dimensionless) |
| NW | Non-Workers (men) |
| TW | Training Workers (men) |
| PWO | Production WOrkers (men) |

## Salary Sector

The average salary for people in the city and its governing policies are relevant parts of the system under study. The salary sector interacts with the consumption sector, which will influence the desired level of production some time thereafter, and thus will change the entrepreneurs desires for hiring or firing people. Once the labor structure has changed, it also will create additional pressures upon salaries.

Although salary itself can be interpreted as a varying money level affected by an incoming rate and an outgoing rate of money, it can also be interpreted as a level "concept" related to the information network, and affected only by the incoming rate. This last interpretation not only oversimplifies the problem's nature, but it also calls for a sharp and clear interpretation of salary as an information concept. In fact, there are important differences between this concept and that of salary as a flow of money. For example, the salary in people's hands is something real which fluctuates from hand to hand, but which nobody can destroy (unless they behave foolishly). Furthermore, even if it is not in people's hands it has to be somewhere: in bank deposits or government deposits. However, salary as an information concept always exists in people's minds and it represents the people's capacity to consume during a period of time. This will be the meaning of salaries in the present research, in order to simplify the system. When salary is modeled as a flow of money, it could be necessary to incorporate as interacting subsystems, at least the consumption multiplier of the economy, the saving level and the fluctuating monetary and fiscal policies of government. On the other hand, when working with the information salary concept, such factors can be implemented in a somewhat easier way. Suppose, for example, that the average nominal salary for a man is \$300 and he expends a maximum percentage of this salary in consuming finished goods and services. The delayed effect of this consumption is to generate an additional demand for intermediate goods, and it also generates other services. The more personal consumption increases, the more the aggregate demand for

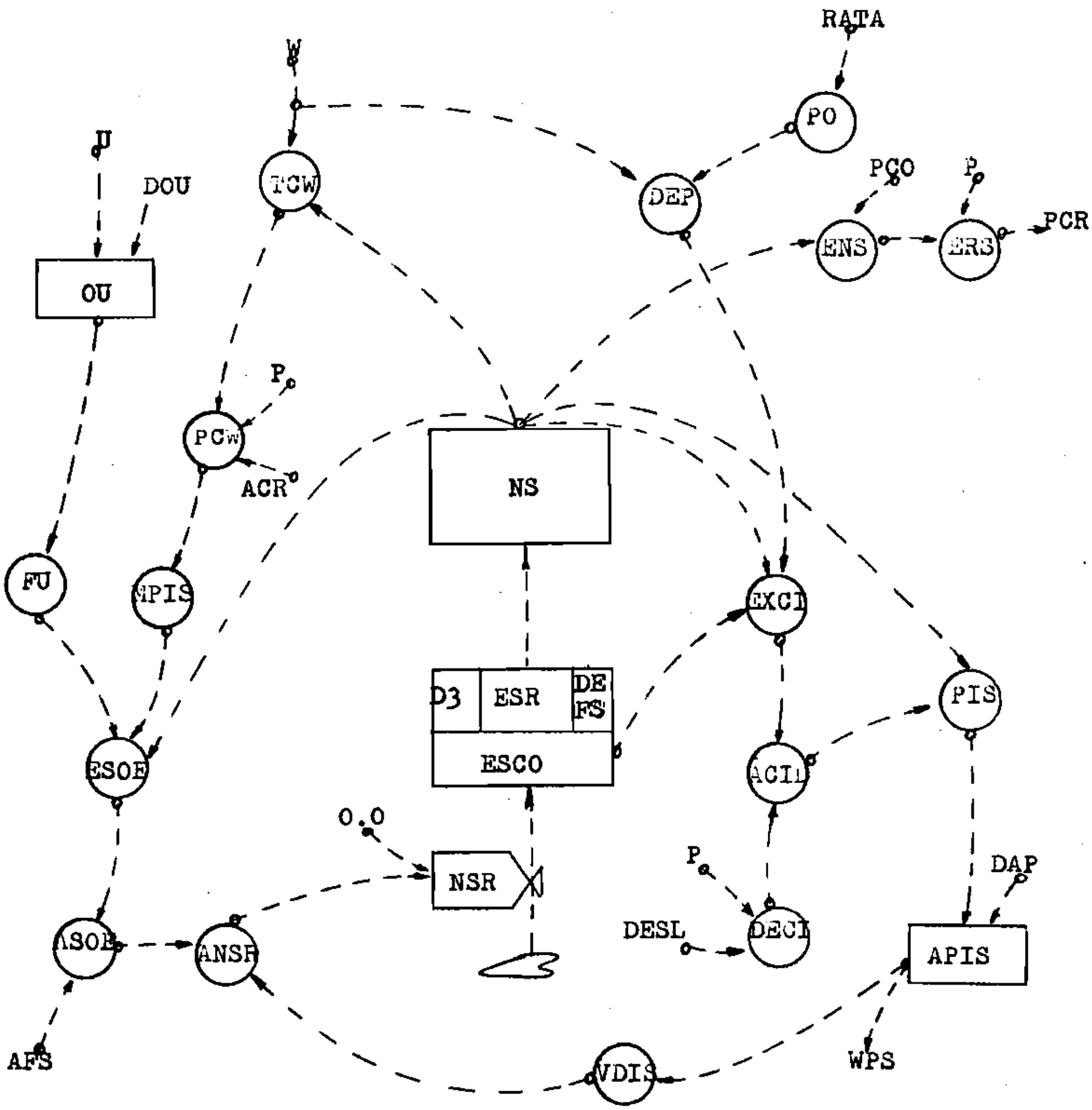



Fig. 10. Salary Sector

goods and services increases (multiplier effect); however, it must be observed that for the intermediate goods, the "customers" are entreprises and not people themselves. Under those circumstances, it might be said that a consumer generates an overhead consumption capacity greater than is equivalent to those $300. Furthermore, if we include some appropriate delays when modeling the production sector, we can assume that the total potential consumption capacity for a worker is his own consumption plus the overhead capacity generated by him. This is one of the assumptions of this model, and perhaps it is also one of its limitations.

The level equation for the nominal salary (averaged over the workers) is (Fig. 10):

$$NS.K = NS.J + (DT)(ESR.JK - 0) \qquad (20L)$$

| | |
|---|---|
| NS | average Nominal Salary (\$/man/month) |
| ESR | Effective Salary Rate (\$/man/month$^2$) |
| 0 | To fit DYNAMO equation form |

In most situations, there exists a delay between the time a salary increase is approved by the entrepreneur and the time workers actually begin to receive the new salary. For this reason, we must define a level as salary in transit or extra salary coming:

$$ESCO.K = ESCO.J + (DT)(NSR.JK - ESR.JK) \qquad (21L)$$

| | |
|---|---|
| ESCO | Extra Salary COming (\$/man/month) |
| NSR | New Salary Rate (\$/man/month$^2$) |
| ESR | Effective Salary Rate (\$/man/month$^2$) |

Some period of time (months) later, the actual new salary rate becomes an effective salary rate. This means that increasing the new salary will affect the salary in transit, and only some months after, the nominal salary will receive its effect.

ERS.KL = DELAY 3(NSR.JK, DEFS) (22R)

| | |
|---|---|
| ERS | Effective Salary Rate ($/man/month) |
| NRS | New Salary Rate |
| DEFS | Delay for EFfective Salary |

This model assumes that the rate at which salaries will increase (or decrease) depends upon the following factors:

(1) A total cost of workers as a fraction of sales per month. The larger this fraction is, the less willing the entrepreneur is to increase salaries. It must be observed that under a poor economic situation, either the total cost of workers can increase in relation to sales or these sales can drop so low that the worker cost percentage is forced upward.

(2) The level of unemployment also affects the desires of the entrepreneur for new increases in salaries. The greater the number of non-workers in the city, the lower the willingness of the entrepreneur to increase salaries. In this case, the manager may even dismiss some of his people because the lost workers can be easily replaced.

These two factors are related to the entrepreneur's information or perception and will affect his desires concerning the workers' salaries. However, the third influencing factor is related only to workers' desires.

(3) The number of people supported by the worker coupled with the

desired standard of living determine pressures for increasing salaries which make the salary level change slower or faster. The greater the pressures for increasing salaries, the quicker the change in salaries.

Those equations describing the first two assumptions will be developed next.

$$TCW.K = (W.K)(NS.K) \tag{23A}$$

| | |
|---|---|
| TCW | Total Cost of Workers ($/month) |
| W | total level of Workers (men) |
| NS | Nominal Salary ($/man/month) |

The total cost of workers expressed as a fraction of the average sales per month is:

$$PCW.K = \frac{TCW.K}{(ACR.K)(P.K)} \tag{24A}$$

| | |
|---|---|
| PCW | Percentage (fraction) Cost of Workers (dimensionless) |
| TCW | Total Cost of Workers ($/month) |
| ACR | Average Consumption per month (units/month) |
| P | Price level ($/unit) |

We have taken the average sales per month, instead of the current sales per month, because it is more likely that the entrepreneur will make decisions on the basis of the sales he has observed during the previous months. Furthermore, it is impossible for him to know the sales volume at the present time.

When the entrepreneur determines the actual percentage of sales expended in labor costs, he decides the maximum percentage of salary increase he is willing to offer. Here we must enter a subjective factor into the model, and it must be considered as an additional hypothesis. We shall assume that the behavior of the maximum percentage of salary increase is the following (Fig. 11) when related to the percentage cost of workers:

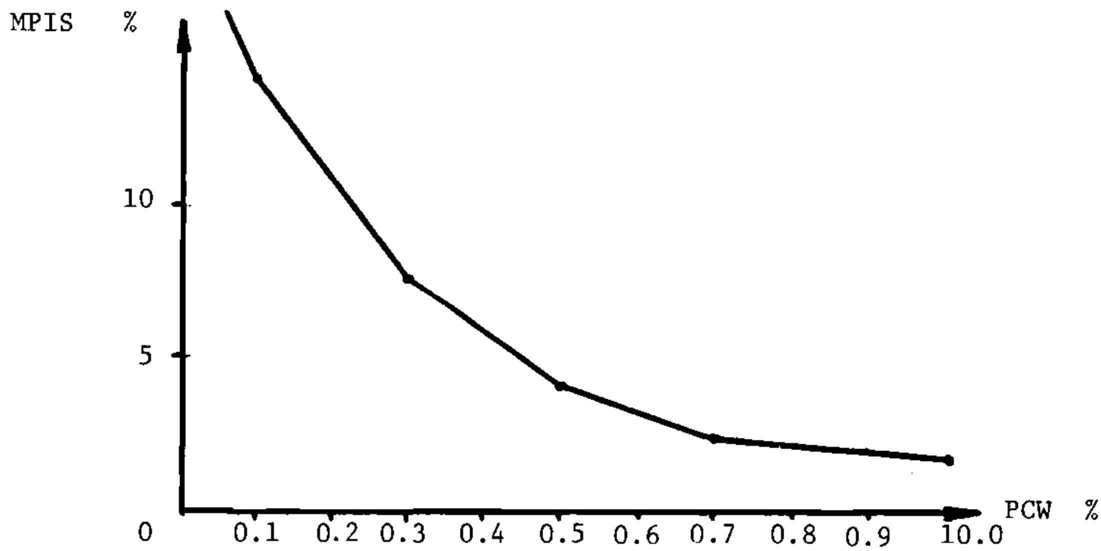



Fig. 11. Maximum Percentage of Salary to Increase as a Function of the Percentage Cost of Workers

The above pattern says that when the fraction representing the cost of workers is increasing, the maximum percentage increase in salaries will decrease. Furthermore, the shape of the curve is convex (from the origin) because for the lowest values of PCW, the entrepreneur's restrictions against increasing salaries are the least, while the opposite is true for the highest values of PCW. Whether the values selected for MPIS be relevant or not is a less important aspect. Industrial dynamics models are not so sensitive to high accuracy in parameters, nor must they be judged from this point of view, but rather by analyzing the whole structure of the model and the behavior of the system (5, page 123). However, those selected values seem to be within a reasonable range.

$$MPIS.K = TABHL(TPIS, PCW.K, 0, L, 0, 1, 0.1) \qquad (25A)$$

MPIS Maximum Percentage to Increase Salaries (dimensionless)

TABHL Table Function

PCW Percentage (fraction) Cost of Workers (dimensionless)

The maximum percentage to increase salaries is affected by the number of unemployed persons in the system. If this number is high, the entrepreneur can offer a lower percentage of salary increase (assumption (2). Suppose that the entrepreneur obtains information about the number of non-workers (not necessarily the "true" number, but an average, say $\overline{NW}$). He thinks that some of his workers can be replaced by some of these non-workers. If all entrepreneurs think the same way during periods of high unemployment, we probably can generalize and conclude that the managerial side can eventually replace just $\overline{NW}$ workers and still offer the same salary (NS). Under this assumption, entrepreneurs are willing to offer an increase in salaries to only $W - \overline{NW}$ workers.

The new prospective cost of workers would be the following:

$$(\overline{NW})(NS) + (W - \overline{NW})(NS + \delta)$$

where $\delta$ is the extra salary offered to the rest of the workers:

$$\delta = (MPIS)(NS)$$

As the net number of workers, W, is still the same $(W + \overline{NW} - \overline{NW})$, the new average nominal salary would be:

$$\frac{1}{W}\,(\overline{NW})(NS) + (W - \overline{NW})(NS + \delta) = NS + \delta - \frac{\overline{NW}}{W}\,\delta$$

and the salary increase offered

$$\delta(1 - \frac{\overline{NW}}{W} = (MPIS)(NS)\ 1 - \frac{\overline{NW}}{W} \qquad \text{(a)}$$

Even though the above equation may be introduced into the set of equations, we must express it as a function of unemployment. As $\overline{NW}$ is an average over time of NW, we shall define observed (average) unemployment as:

$$OU = \frac{\overline{NW}}{W + \overline{NW}}$$

or

$$1 - \frac{\overline{NW}}{W} = \frac{1 - 2(OU)}{1 - (OU)} = FU$$

The observed unemployment also can be calculated from the actual unemployment. They are related by an average smoothing equation:

$$OU.K = OU.J + (DT)\,\frac{1}{DOU}\,(U.J - OU.J) \qquad \text{(26L)}$$

| | |
|---|---|
| OU | Observed Unemployment (dimensionless) |
| U | Unemployment (dimensionless) |
| DOU | Delay in Observing Unemployment (months) |

The factor FU is the value of the influence of unemployment upon the extra salary offered:

$$FU.K = \frac{1 - 2(OU.K)}{1 - (OU.K)} \qquad \text{(27A)}$$

FU Factor Unemployment (dimensionless)

OU Observed Unemployment (dimensionless)

Equation (a) becomes:

$$ESOE.K = (MPIS.K)(FU.K)(NS.K) \tag{28A}$$

ESOE Extra Salary Offered ($/man/month)

MPIS Maximum Percentage to Increase Salaries (dimensionless)

FU Factor Unemployment (dimensionless)

NS Nominal Salary ($/man/month)

In the last equation are coupled together assumptions (1) and (2). Increases in the fraction of cost of workers will decrease the maximum percentage to increase salaries and will decrease the extra salary offered; similarly, increases in unemployment (equation 27A) will decrease the factor unemployment (FU) and will decrease the extra salary offered.

The equations related to the workers' pressures to increase salaries and their influence upon the salary rate of change (assumption (3)) can be stated in the following way:

The salary a worker expects for the coming months will be his actual nominal salary (NS) plus the extra salary coming (ESCO); and the fraction of expected salary per person in the city will be equal to the total income of workers divided by the population of the city:

$$\frac{[NS.K + ESCO.K]W.K}{PO.K}$$

The number of people supported by the worker is the dependence factor:

$$DEP.K = \frac{PO.K}{W.K} \tag{29A}$$

DEP DEPendence factor (dimensionless)

PO POpulation (men)

W total number of Workers (men)

and the fraction of expected salary per person (the expected capital income) becomes:

$$EXCI.K = \frac{NS.K + ESCO.K}{DEP.K} \tag{30A}$$

EXCI EXpected Capital Income ($/man/month)

NS Nominal Salary ($/man/month)

ESCO Extra Salary COming ($/man/month)

DEP DEPendence factor (dimensionless)

We can assume that the workers' pressures for increasing salaries do exist because people think there is a gap between their expected capital income and their own desires for goods and services. In other words, there exists a difference between their expected capital income and their desired capital income.

$$DECI.K = (DESC)(P.K) \tag{31A}$$

DECI DEsired Capital Income ($/man/month)

DESL DEsired Standard of Living (units/man/month)

P Price level ($/unit)

In an aggregate economy, where there are different kinds of goods and services, it is difficult to define a realistic measure for the desired standard of living. We assume here that a "unit" of goods and services is a unit of a specific good which people buy because it gives satisfaction and which is scarce because of the limited resources of the city. It costs an amount of money equal to the price level.

The additional capital income desired will be as follows:

$$ACID.K = DECI.K - EXCI.K \tag{32A}$$

| | |
|---|---|
| ACID | Additional Capital Income Desired (\$/man/month) |
| DECI | DEsired Capital Income (\$/man/month) |
| EXCI | EXpected Capital Income (\$/man/month) |

This expression can represent the pressures of workers for increasing salaries. The higher the price level, the greater their dissatisfaction and the greater the pressures upon salaries. On the other hand, the higher the expected capital income, the lower the pressures upon salaries. However, these pressures also can be represented as a fraction of the nominal salary. In this way, the measure of the pressures for increasing salaries will be even more realistic. Although pressures for increasing salaries probably will increase with time, it is also true that these pressures fluctuate from time to time. For example, during periods of strikes, the value of these pressures can be so high that the entrepreneur decides upon a quicker adjustment of salaries than he would normally be inclined to do. In this case, the strike can be terminated because the workers' pressures upon salaries have decreased, even though there is still a gap between desired capital income and the new expected capital income. For this reason, the larger the nominal salary, the less the pressures for increasing salaries:

$$PIS.K = \frac{ACID.K}{NS.K} \tag{33A}$$

PIS Pressures for Increasing Salaries (dimensionless)

ACID Additional Capital Income Desires (\$/man/month)

NS Nominal Salary (\$/man/month)

Changes in the above values do not immediately influence the actual pressures for increasing salaries of workers. Rather, they produce their effects some period of time thereafter:

$$APIS.K = APIS.J + (DT)\frac{1}{DAP}(PIS.J - APIS.J) \tag{34L}$$

APIS Actual (average) Pressures for Increasing Salaries (dimensionless)

PIS Pressures for Increasing Salaries (dimensionless)

DAP Delay for Averaging Pressures (months)

If the actual pressures for increasing salaries are high, entrepreneurs probably respond quickly to the workers' petitions. However, even when pressures are the highest, there will always exist a minimum period of time for the entrepreneur to make his decision. On the other hand, if pressures fall below some value not affecting the entrepreneur's perception, he probably will take a much longer time to respond. The above description corresponds with a convex (from the origin) table function (Fig. 12).

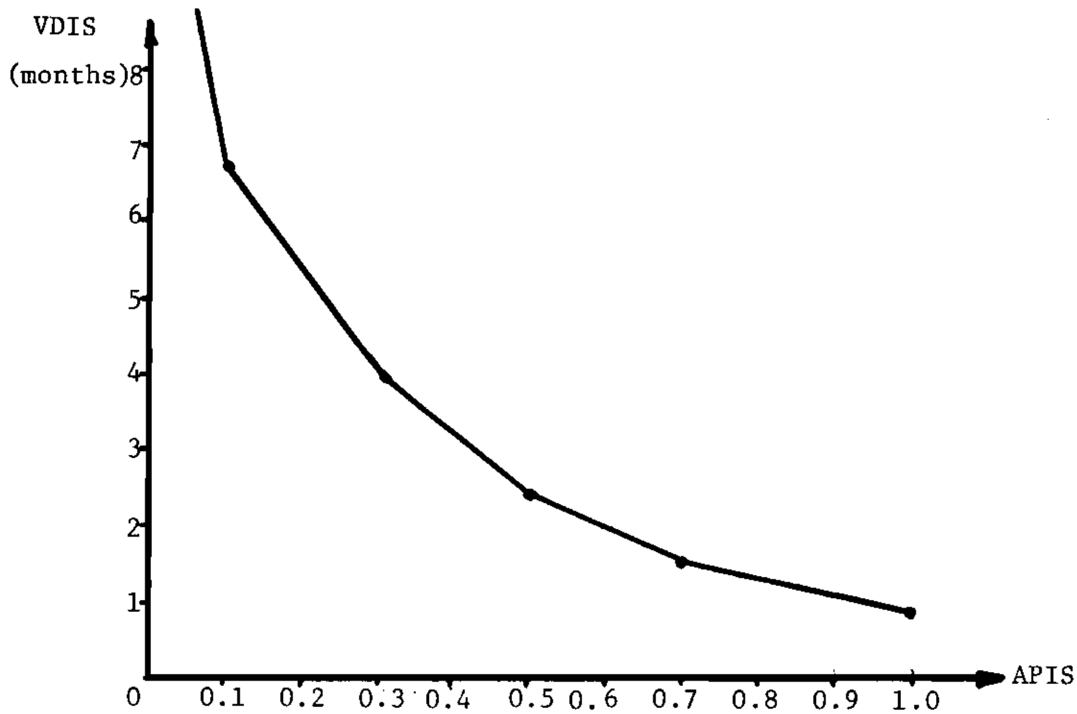



Fig. 12. Variable Delay to Increase Salary

VDIS.K = TABHL(TDIS, APIS.K, 0, 1, 0.1) (35A)

VDIS Variable Delay for Increasing Salaries (months)

APIS Actual Pressures for Increasing Salaries (dimensionless)

Now we must return to equation 28A. Each month, the entrepreneur will correct a fraction of his extra salary offered (ESOE). The next equation to develop is an auxiliary expression used only for the purpose of testing sensitivity of the two table function values.

ASOE.K = (AFS)(ESOE.K) (36A)

ASOE Auxiliary for Sensitivity ($/man/month)

AFS testing parameter (dimensionless)

The new salary incoming rate is:

$$ANSR.K = \frac{ASOE.K}{VDIS.K} \tag{37A}$$

| | |
|---|---|
| ANSR | Auxiliary for New Salary Rate (\$/man/month) |
| ASOE | Auxiliary for Sensitivity. A function of Extra Salary Offered by Entrepreneurs (\$/man/month) |

Finally, the new salary rate will be:

$$NSR.KL = MAX\ (0,\ ANSR.JK) \tag{38R}$$

| | |
|---|---|
| NSR | New Salary Rate (\$/man-month$^2$) |
| ANSR | Auxiliary for New Salary Rate (\$/man-month$^2$) |

We have assumed that this incoming rate is always positive. Many countries, mainly those which are underdeveloped, have laws which make it virtually impossible to decrease the nominal salary. The model does not assume the possibility of a black market for labor, which could exist under situations of high unemployment.

The last two equations deal with the effective nominal salary and the effective real salary. We must suppose that under some circumstances workers will expend only a fraction of their salary. There are people who normally have savings, but we assume that these amounts are rather small.

$$ENS.K = (PCO)(NS.K) \tag{39A}$$

| | |
|---|---|
| ENS | Effective Nominal Salary (\$/man-month) |
| PCO | Percentage to COnsumption (dimensionless) |

NS Nominal Salary ($/man-month)

The effective real salary will be the ratio between the effective nominal salary and the price level:

$$ERS.K = \frac{ENS.K}{P.K} \tag{40A}$$

ERS Effective Real Salary (units/man-month)

ENS Effective Nominal Salary ($/man-month)

P Price level ($/unit)

## Production and Consumption Sector

The production and consumption sector is probably one of the most important parts of the system under study. The varying number of workers and their salaries determine the actual personal consumption capacity which, in turn, influences inventories and backlogs at factories and other enterprises. Once entrepreneurs have considered their inventories, backlogs, and the total consumption, they decide how many units to produce for the next month and how many workers they need to support their new rate of production. The new workers hired (or fired) will change the labor force structure, which will affect the nominal salary and will again produce new changes in the consumption rate. The above chain of causes and effects represents a positive feedback: the more the consumption, the more the entrepreneurs' desires for increasing production, which in turn, increases the indicated desires for new workers. The larger this factor is, the greater the number of people, and, after a delay, the higher the number of workers, which results in an increase in consumption.

The production sector also interacts with the labor-saving techniques (equipment) sector and has an additional kind of relationship with the labor force. However, in both cases, the related feedback is a negative one. When the production rate is increasing, we must expect an increase in inventories for a time thereafter. If inventories are augmenting faster than consumption, entrepreneurs will try to decrease their production rate. The longer this situation persists, the stronger the entrepreneurs' desires to use less equipment and workers, which finally will cause a diminishing production rate.

The production operation is represented here by an aggregate flow of goods and services, and it also is influenced by a flow of orders in backlog at enterprises. Although this level of aggregation is so broad that it is difficult to define its most appropriate units, it is also true that it assumes two additional conditions (5, p. 110): First, all items and services in the flow must be controlled by the same decision function, and second, all the controlled outputs of this part of the system must be used for identical purposes elsewhere in the model -- in the labor sector, in the labor-saving techniques (equipment) sector, and in the people's and entrepreneurs' confidence sector. Under those circumstances, we must include the above two assumptions in the model, even though their validity in the actual system may be a matter for discussion.

The flow of goods (Fig. 13) consists of two levels: a level for goods and services in process and a level for inventories.

$$GIP.K = GIP.J + (DT)(PRR.JK - IR.JK) \quad (41L)$$

GIP Goods In Process (units)

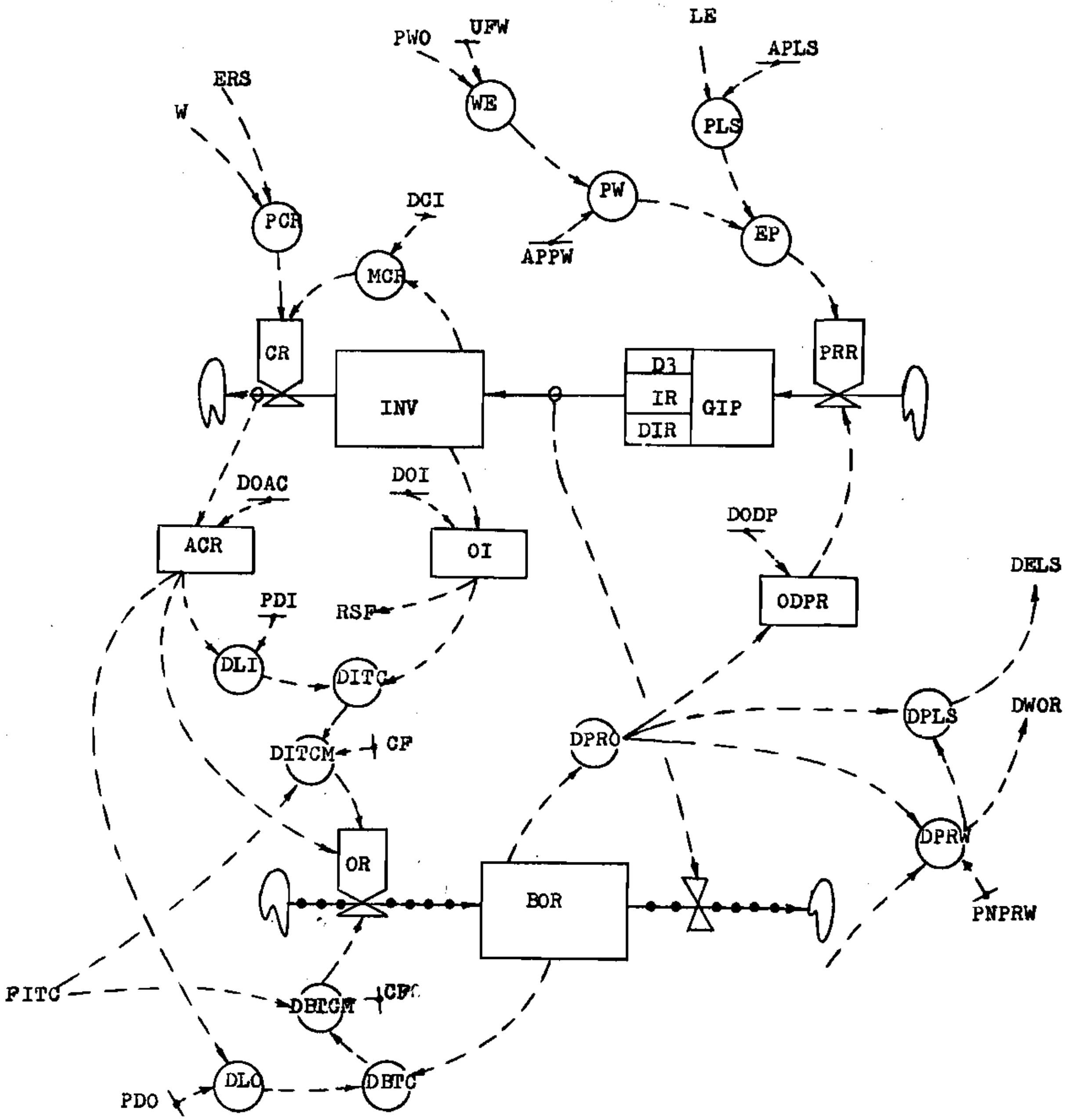



Fig. 13. Production and Consumption Sector

PRR PRoduction Rate (units/month)

IR Inventory (in) Rate (units/month)

Changes in the production rate do not immediately affect inventories. It takes time for this to occur, mainly for two reasons: first, factories need time to adjust to the new level of production, and second, there is an interval between the time items are beginning to be produced and the time they actually are finished. However, in the aggregate economy, with the wide variety of goods to be produced, we must expect some of the goods to be finished first, others later. This situation can be represented with some degree of reality by a third exponential delay:

$$IR.KL = DELAY\ 3(PRR.JK,\ DIR) \qquad (42R)$$

IR Inventory (in) Rate (units/month)

PRR PRoduction Rate (units/month)

DIR Delay for Inventory Rate (months)

and

$$INV.K = INV.J + (DT)(IR.JK - CR.JK) \qquad (43L)$$

INV INVentory level (units)

IR Inventory (in) Rate (units/month)

CR Consumption Rate (units/month)

The consumption rate depends upon the nominal salary and the total level of workers. However, the concept developed when we defined the nominal salary must be remembered here. We said that salary can represent the worker's potential capacity for consumption. This concept takes into account the personal consumption of workers (finished goods) plus the additional consumption of intermediate goods generated (p.45). Then we can define a potential consumption rate in the following way:

$$PCR.K = (W.K)(ERS.K)(CEXPF) \tag{44A}$$

| | |
|---|---|
| PCR | Potential Consumption Rate (units/month) |
| W | total level of Workers (men) |
| ERS | Effective Real Salary (units/man-month) |
| CEXPF | Constant EXPortation Factor |

In the above equation, we have assumed that the city exports some amount of goods which is proportional to the volume of goods consumed in the city. The actual consumption rate cannot be greater than that value which causes inventories to become negative:

$$MCR.K = \frac{INV.K}{DCI} \tag{45A}$$

| | |
|---|---|
| MCR | Maximum Consumption Rate (units/month) |
| INV | INVentories (units) |
| DCI | Delay in Consuming Inventories (months) |

and the actual consumption rate will be:

$$CR.KL = MIN(PCR.K, MCR.K) \tag{46R}$$

| | |
|---|---|
| CR | Consumption Rate (units/month) |
| PCR | Potential Consumption Rate (units/month) |
| MCR | Maximum Consumption Rate (units/month) |

The order rate for goods and services at factories, enterprises, or in the government depends principally upon three factors: the observed sales per month, the observed inventories, and the order backlog at factories, enterprises, and in the government. Furthermore, as entrepreneurs always accept a certain level of goods in inventories as normal, we can assume that when inventories are higher than this normal value, entrepreneurs will decrease their order rate at factories. Otherwise, they will increase it. Similarly, if the order backlog is higher (lower) than a normal volume of orders, entrepreneurs also will decrease (increase) their order rate at factories. Under these circumstances, we may assume that the production function has three objectives:

(1) To maintain the volume of sales for the coming months (aggregate consumption rate).

(2) To maintain a certain desired level of inventories.

(3) To maintain a certain desired level of orders in backlog.

Entrepreneurs' decisions depend not only upon the observed actual values, but also upon the observed values in the past. This is the case for sales and inventories:

$$\text{ACR.K} = \text{ACR.J} + (\text{DT}) \frac{1}{\text{DOAC}} (\text{DR.JK} - \text{ACR.J}) \tag{47L}$$

| | |
|---|---|
| ACR | Average Consumption Rate (units/month) |
| CR | Consumption Rate (units/month) |
| DOAC | Delay in Observing Average Consumption (months) |

and

$$\text{OI.K} = \text{OI.J} + (\text{DT}) \frac{1}{\text{DOI}} (\text{INV.J} - \text{OI.J}) \tag{48L}$$

OI Observed Inventory (units)

INV INVentory (units)

DOI Delay in Observing Inventory

The rate of orders for goods and services in the aggregate economy is a function of the average consumption rate, the desired inventory to control per month, and the desired backlog of orders to control per month. The model assumes that the desired level of inventories and the desired level of orders in the backlog are proportional to the average consumption rate:

$$DLI.K = (PDI)(ACR.K) \tag{49A}$$

DLI Desired Level of Inventory (units)

PDI Percentage for Desired Inventory (months)

ACR Average Consumption Rate (units/month)

and

$$DLO.K = (PDO)(ACR.K) \tag{50A}$$

DLO Desired Level of Orders (units)

PDO Percentage for Desired Orders (month)

ACR Average Consumption Rate (units/month)

The difference between the desired level of inventory and the observed inventory is the desired inventory to control. However, entrepreneurs will correct only a fraction of the above difference each month. A similar assumption follows for the desired backlog of orders to control.

$$DITC.K = DLI.K - OI.K \tag{51A}$$

DITC Desired Inventory to Control (units)

DLI Desired Level of Inventory (units)

OI Observed Inventory (units)

and

$$DBTC.K = DLO.K - BOR.K \tag{52A}$$

DBTC Desired Backlog To Control (units)

DLO Desired Level of Orders (units)

BOR Backlog of ORders (units)

The desired inventory to correct per month is represented by the following equation:

$$DITCM.K = \frac{DITC.K}{FITC.K} (CF) \tag{53A}$$

DITCM Desired Inventory To Correct per Month (units/month)

DITC Desired Inventory To Correct (units)

FITC Fraction Inventory To Correct (months)

CF Constant Factor for testing sensitivity of FITC

and the desired backlog to correct per month:

$$DBTCM.K = \frac{DBTC.K}{FITC.K} (CF) \tag{54A}$$

DBTCM Desired Backlog To Correct per Month (units/month)

DBTC Desired Backlog To Correct (units)

FITC Fraction Inventory To Correct (months)

CF Constant Factor for testing sensitivity of FITC

The present model assumes that entrepreneurs will try to correct the same proportion of their desired inventory and backlog each month. However, it seems likely to believe that this fraction to control is related to the entrepreneur's confidence in the economic activity of the city. We shall come back to this point when we define the entrepreneur's confidence in the system (p. 24).

At this point, we can state the rate of orders for goods (or services) at factories (or enterprises):

$$\mathrm{OR.KL = ACR.K + DITCH.K + DBTCM.K} \qquad \mathrm{(55R)}$$

OR Orders Rate (units/month)

ACR Average Consumption Rate (units/month)

DITCM Desired Inventory To Control per Month (units/month)

DBTCM Desired Backlog To Control per Month (units/month)

The level of orders in backlog is affected by the above incoming rate and it also is affected by the incoming rate of goods to inventories. In other words, when items are leaving from the goods in process level (GIP) and entering the inventory level, entrepreneurs discharge the same amount of orders from their backlog.

$$\mathrm{BOR.K = BOR.J + (DT)(OR.JK - IR.JK)} \qquad \mathrm{(56L)}$$

BOR Backlog of ORders (units)

OR Orders Rate (units/month)

IR Inventory (in) Rate (units/month)

This backlog of orders represents the total volume of goods and services which the city would produce during the next month if:

(a) the manpower and equipment capacity were sufficient,

(b) the actual manpower and equipment could be adjusted to the new level of activity within a very short period of time (much less than a month).

The above two conditions determine the actual production rate. The first condition deals with the expected production or actual production capacity of the city, whereas condition (b) introduces a delay for adjusting new rates of production. Those equations related to the last assumption will be developed first.

The desired production for the next month is a fraction of the actual backlog of orders:

$$\text{DPRO.K} = (\text{FOTP})(\text{BOR.K}) \qquad (57\text{A})$$

DPRO Desired PROduction for next month (units/month)

BOR Backlog of ORders (units)

FOTP Fraction of Orders To Produce during the next month (1/month)

and the delay for adjusting the rates of production to the new desired values is:

$$\text{ODPR.K} = \text{ODPR.J} + (\text{DT})\,\frac{1}{\text{DODP}}\,(\text{DPRO.J} - \text{ODPR.J}) \qquad (58\text{L})$$

ODPR Observed Desired PRoduction (units/month)

DPRO Desired PROduction (units/month)

DODP Delay for Observing and adjusting the Desired Production (months)

The next set of five equations is related to the actual production capacity of the city (condition (a)). It will be called the expected production, and it assumes two sources of production:

(1) Capital-intensive techniques with very high productivity compared to the workers' productivity.

(2) Production workers with a low productivity.

Equations related to labor-saving techniques productivity (equipment productivity) are:

$$LE.K = (UFL)(LST.K) \tag{59A}$$

LE Labor-saving techniques (Effective) (capital units)

LST Labor-Saving Techniques (equipment) (capital units)

UFL Utilization Factor for Labor-saving techniques (dimensionless)

and

$$PLS.K = (APLS)(LE.K) \tag{60A}$$

PLS Production of Labor-Saving techniques (units/month)

APLS Average Productivity of Labor-Saving techniques (units/capital units/month)

LE Labor-saving techniques (Effective) (capital units/ month)

The two equations related to the workers' productivity are:

$$WE.K = (UFW)(PWO.K) \quad (61A)$$

| | |
|---|---|
| WE | Workers (Effective) (men) |
| UFW | Utilization Factor for Workers (dimensionless) |
| PWO | Production WOrkers (men) |

and

$$PW.K = (APPW)(WE.K) \quad (62A)$$

| | |
|---|---|
| PW | Production of Workers (units/month) |
| APPW | Average Productivity Per Worker (units/man-month) |
| WE | Workers (Effective) (men) |

The above utilization factors (UFL, UFW) represent the actual number of capital units and workers in production. However, UFW also takes into account those workers needed for operation of equipment in the labor-saving techniques sector; for this reason, WE only represents people working in labor-intensive manufacturing and presumably with a lower productivity than those workers in the equipment (labor-saving techniques) sector:

The total expected production per month will be:

$$EP.K = PLS.K + PW.K \quad (63A)$$

| | |
|---|---|
| EP | Expected Production (units/month) |
| PLS | Production of Labor-Saving techniques (units/month) |
| PW | Production of Workers (units/month) |

At this point, we have defined both the entrepreneurs' observed desired production (ODPR) for the next month and the expected production (EP) per month. The actual production rate will be the lesser of EP or ODPR.

PRR.KL - MIN(ODPR.K, EP.K) (64R)

| | |
|---|---|
| PRR | PRoduction Rate (units/month) |
| ODPR | Observed Desired PRoduction (units/month) |
| EP | Expected Production (units/month) |

Finally, we must assume that once entrepreneurs have defined their desired production for the next month (DPRO), they select the level of goods which the worker and equipment sectors will produce:

DPRW.K = (PNPRW)(DPRO.K)(PTUW.K) (65A)

| | |
|---|---|
| DPRW | Desired PRoduction for Workers (units/month) |
| PNPRW | PerceNtage of desired PRoduction for Workers (dimensionless) |
| DPRO | Desired PROduction (units/month) |
| PTUW | Propensity To Use Workers (dimensionless) |

and

DPLS.K = DPRO.K - DPRW.K (66A)

| | |
|---|---|
| DPLS | Desired Production for Labor-Saving (units/month) |
| DPRO | Desired PROduction (units/month) |
| DPRW | Desired PRoduction of Workers |

Labor-Saving Techniques Sector

The labor-saving techniques sector represents the high-productivity equipment available within the city as well as the governing policies which rule the acquisition and discharge equipment (Figure 14). This sector interacts with the production sector in such a way that when new equipment is acquired, there is an increase in the expected production, which eventually will increase the production rate of goods. Although this rate has a positive effect upon goods in process and inventories, its delayed effect upon the equipment sector also depends on the average consumption rate. If this value is so high that entrepreneurs are not worried about increases in inventories, then the desired inventory to control (DITC) will increase the backlog of orders at the factories, which will cause the desired production (DPRO) to increase and will influence the actual level of equipment after some delay. In this case, the existing feedback is a positive one. On the other hand, if the average consumption rate is so small that entrepreneurs do not like to see their inventories increasing, then the desired inventory to control (DITC) will become negative, which will decrease the backlog of orders at the factories. The diminishing backlog causes the desired production to decrease, resulting in a lowering of the desire for equipment and the actual level of equipment in use. In this case, the existing feedback is negative.

The related equations of this sector follow a concept similar to those defining the labor sector. Two main levels of equipment, labor-saving techniques in transit and labor-saving techniques, define the flow of capital goods, and the flow itself is ruled by three decisions: the labor-saving "in" rate, the labor-saving techniques rate, and the labor-saving "out" rate (Figure 14). As in the labor force sector, we must introduce some delayed information (smoothing equation levels) as well as the same type of delays used there. Explanation of these will be omitted here.

The labor-saving techniques in transit level is:

$$LSTT.K = LSTT.J + (DT)(LSIR.JK - LSTR.JK) \tag{67L}$$

| | |
|---|---|
| LSTT | Labor-Saving Techniques in Transit (capital units) |
| LSIR | Labor-Saving In Rate (capital units/month) |
| LSTR | Labor-Saving Techniques Rate (capital units/month) |

and the labor-saving techniques level is:

$$LST.K = LST.J + (DT)(LSTR.JK - LSOR.JK) \tag{68L}$$

| | |
|---|---|
| LST | Labor-Saving Techniques (capital units) |
| LSTR | Labor-Saving Techniques Rate (capital units/month) |
| LSOR | Labor-Saving techniques Out Rate (capital units/month) |

The desire for labor-saving capital units will be:

$$DELS.K = \frac{DPLS.K}{APLS} \tag{69A}$$

| | |
|---|---|
| DELS | DEsire for Labor-Saving techniques (capital units) |
| APLS | Average Productivity of a unit of Labor Saving (units/capital unit/month) |
| DPLS | Desired Production by Labor-Saving (units/month) |

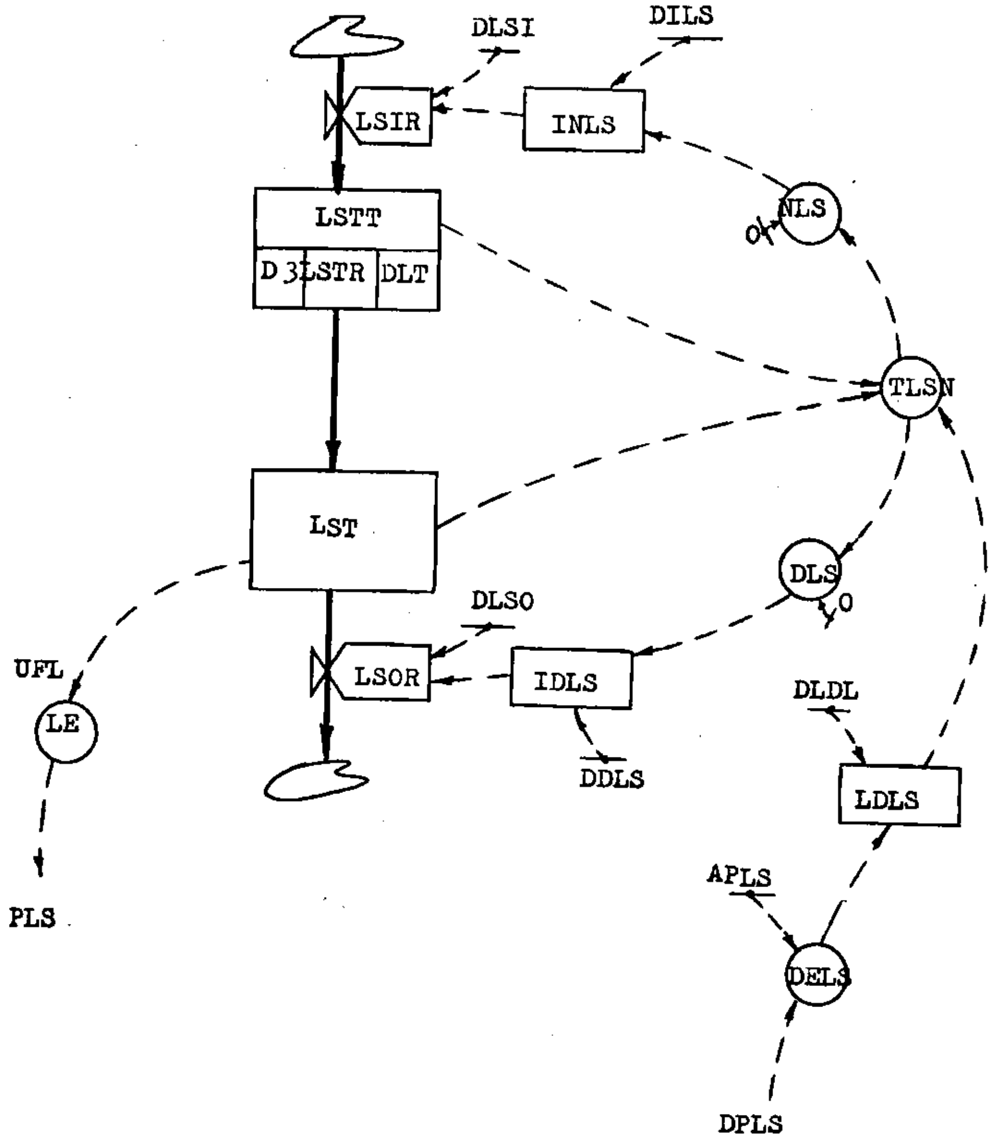



Fig. 14. Labor Saving Techniques Sector

This variable must be delayed over a period of time in which entrepreneurs adjust their convictions about the new conditions of the system:

$$ODLS.K = ODLS.J + (DT)\frac{1}{DLDL}(DELS.J - ODLS.J) \qquad (70L)$$

| | |
|---|---|
| ODLS | Observed Desire for Labor Saving (capital units) |
| DLDL | DeLay for Desired Labor saving (months) |
| DELS | DEsire for Labor Saving (capital units) |

The total number of capital units needed will be the difference between the above variable (ODLS) and the total number of labor-saving units (actual and in transit):

$$TLSN.K = ODLS.K - LSTT.K - LST.K \qquad (71A)$$

| | |
|---|---|
| TLSN | Total number of Labor-Saving units Needed (capital units) |
| LST | Labor-Saving Techniques (capital units) |

The above variable may be positive or negative. If it is positive, entrepreneurs will plan to acquire more equipment. Otherwise they will plan to discharge equipment.

$$NLS.K = MAX(0,TLSN.K) \qquad (72A)$$

$$DLS.K = MAX(0, - TLSN.K) \qquad (73A)$$

| | |
|---|---|
| NLS | New Labor-Saving techniques (capital units) |
| DLS | Discharged Labor-Saving techniques (capital units) |
| TLSN | Total Labor-Saving Needed (capital units) |

The intended number of new labor-saving units and the intended number of discharged labor-saving units are represented by the following equations:

$$\text{INLS.K} = \text{INLS.J} + (\text{DT})\,\frac{1}{\text{DILS}}\,(\text{NLS.J} - \text{INLS.J}) \qquad (75L)$$

$$\text{IDLS.K} = \text{IDLS.J} + (\text{DT})\,\frac{1}{\text{DDLS}}\,(\text{DLS.J} - \text{IDLS.J}) \qquad (76L)$$

| | |
|---|---|
| NLS | New Labor-Saving units (capital units) |
| DLS | Discharged Labor-Saving units (capital units) |
| DILS | Delay for Intended new Labor-Saving units (months) |
| DDLS | Delay for Discharge of Labor-Saving units (months) |

For an explanation of this type of delay-smoothing equation, see equations 13L and 17L in the Labor Sector.

Finally, the three rates governing the flow of capital goods are:

$$\text{LSIR.KL} = \frac{\text{INLS.K}}{\text{DLSI}} \qquad (77R)$$

| | |
|---|---|
| LSIR | Labor Savings In Rate (capital units/ month) |
| INLS | Intended New Labor-Saving units (capital units) |
| DLSI | Delay for Labor Savings In (months) |

$$\text{LSTR.KL} - \text{DELAY 3}(\text{LSIR.JK, DLT}) \qquad (78R)$$

| | |
|---|---|
| LSTR | Labor Saving Techniques Rate (capital units/month) |
| LSIR | Labor-Saving In Rate (capital units/month) |
| DLT | Delay for Labor-saving units in Transit (months) |

$$LSOR.KL = \frac{IDLS.K}{DLSO} \tag{79R}$$

| | |
|---|---|
| LSOR | Labor Saving Out Rate (capital units/month) |
| IDLS | Intended Discharge of Labor-Saving units (capital units) |
| DLSO | Delay for Labor Savings Out (months) |

## People's and Entrepreneurs' Confidence Sector

This sector defines those relationships which presumably represent the people's confidence in the system as well as the entrepreneurs' confidence in the system. These two factors are influenced by the labor sector, the salary sector, and the production sector, and they affect the total desired production and the desired production by workers. Changes in the desired production make the production rate and the labor and equipment sector change, which in turn, affects the above two confidence factors.

The model assumes that the people's confidence factor has three components:

(1) A component due to the confidence of unemployed people,

(2) A component due to the confidence of workers, and

(3) A component due to the actual capital income (consumption per person).

On the other hand, it has been assumed that the entrepreneur's confidence in the system is affected by the total confidence of the public system as well as a second factor resulting from the ratio between inventories and consumption.

The definition of the confidence concept represents a very subjective idea. Although it is in fact, a factor hard to define, it is a

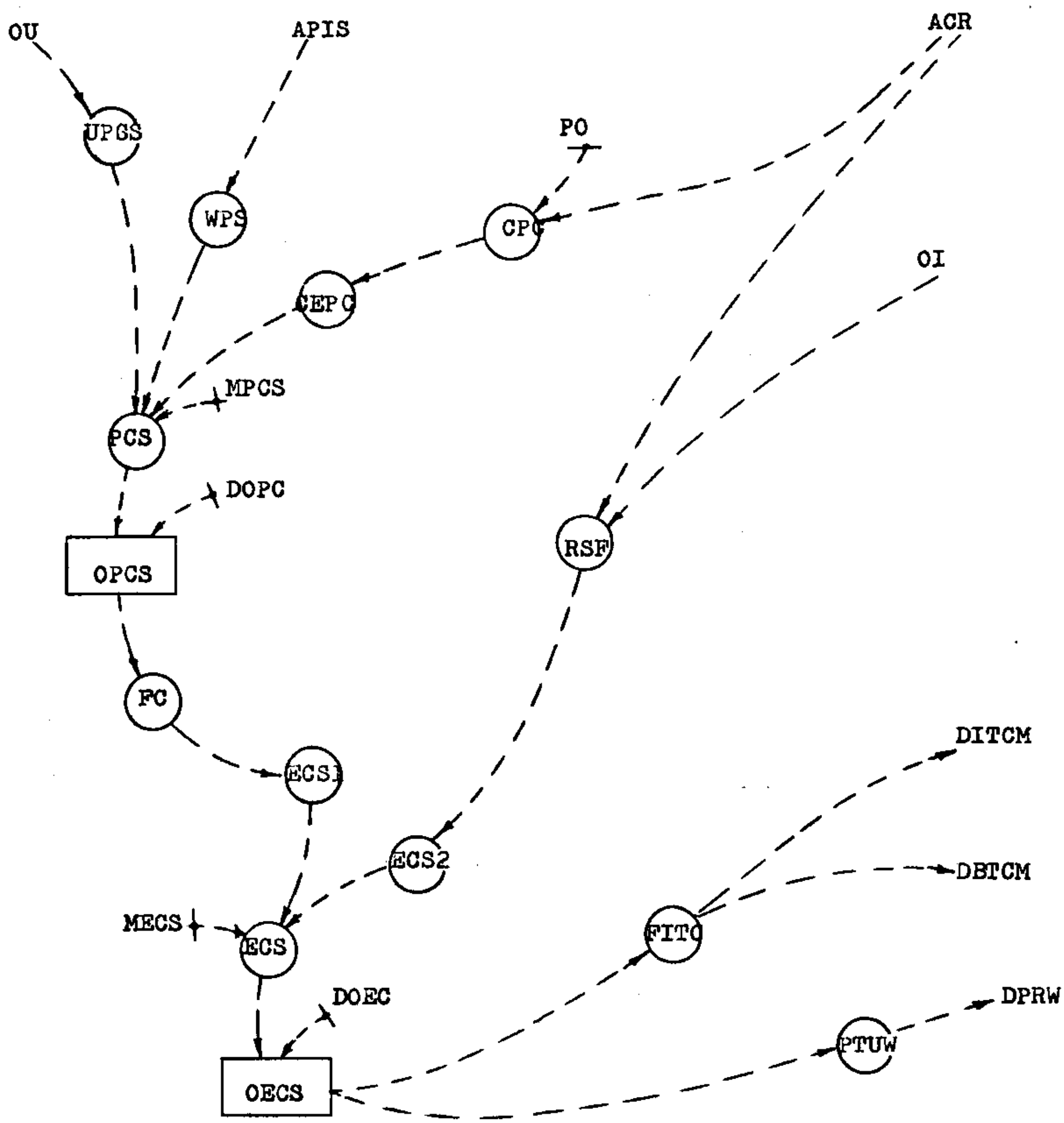



Fig. 15. Confidence Sector

time-variable factor which has a decisive effect on people's decisions. This means that it would be preferable to include the confidence factor, even with its imperfections and subjectiveness, than to omit it completely.

The next set of six equations deals with the people's confidence factor. Table functions define the relationship between the affecting factors and the respective people's confidence components.

The unemployed's confidence in the system can be related to the unemployment percentage as follows:

UPCS.K = TABHL(TUPC, OU.K, 0, 0.25, 0.05) (80A)

| | |
|---|---|
| UPCS | UnemPloyed's Confidence in System |
| OU | Observed Unemployment (confidence units) |
| TUPC | Name for the table |

Figure 16, curve UPCS, represents the assumed relationship. It also has been assumed that the confidence components can change from zero to 100 "confidence units." The function shown says that the unemployed's confidence is not highly sensitive to low values of observed unemployment; however, as the observed unemployment passes 0.1, the related confidence starts moving (decreasing) very rapidly. In other words, when unemployment reaches that value, the unemployment problem begins to be a matter of continuous discussion in the city. This public concern causes the unemployed to have even less confidence in the possibilities for finding jobs than before. However, it can be reasonably assumed that confidence will not be as sensitive to much higher values of unemployment. In this

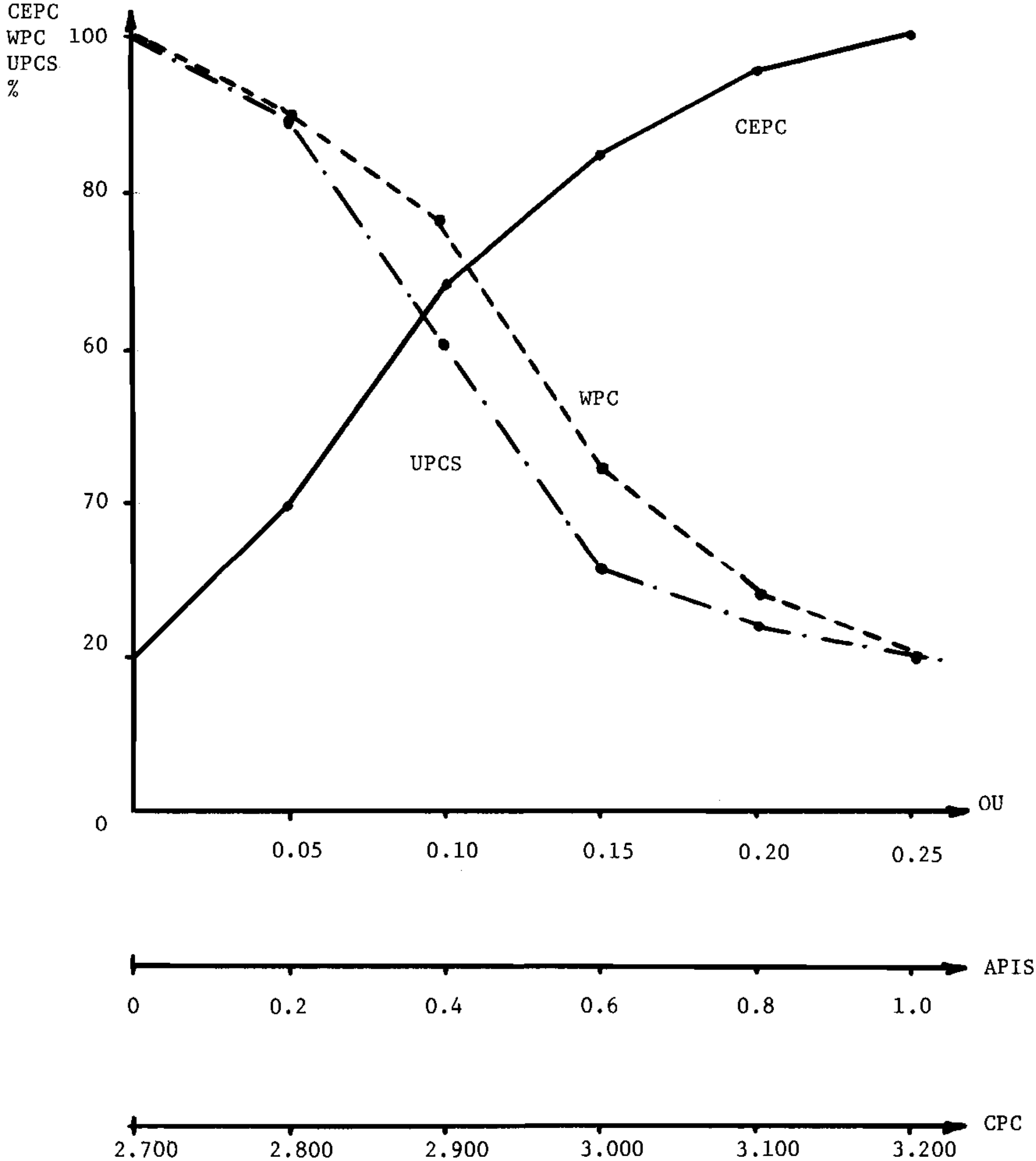



Fig. 16. People Confidence Functions

case ($OU \geq 0.3$), jobless workers probably consider themselves as belonging to a definite group of people with the same problem. (They no longer feel alone or isolated in their situation.) As a result, their identification with the group "supports" their own inner security and, even though their confidence continues decreasing, it probably will not do so faster than in the previous range of observed unemployment (OU).

A similar argument holds for the next kind of confidence component: the workers' confidence (WPS). However, in this case the affecting factor is the (average) pressures for increasing salaries (APIS). The assumed behavior is shown in Figure 16, curve APIS.

$$WPC.K = TABHL(TWPC, APIS.K, 0, 1, 0.2) \tag{81A}$$

| | |
|---|---|
| WPC | Workers' Confidence (confidence) |
| APIS | Average Pressures for Increasing Salaries (dimensionless) |

The last component influencing the people's confidence is related to the consumption per capita:

$$CPC.K = \frac{ACR.K}{PO.K} \tag{82A}$$

| | |
|---|---|
| CPC | Consumption Per Capita (units/men/months) |
| ACR | Average Consumption Rate (units/month) |
| PO | POpulation (input function) (men) |

Figure 16, curve CEPC, represents the consumption effect on people's confidence. It has been assumed that the larger the consumption per capita, the greater the related confidence. However, for this case, the curve is concave (from the origin) for large values of its affecting factor. This means that for relatively very large values of the CPC, the confidence is not very sensitive to stronger changes in its affecting factor (CPC).

$$\text{CEPC.K} = \text{TABHL(TCEP, CPC.K, 2700, 3200, 100)} \qquad (83A)$$

CEPC Consumption Effect on People's Confidence (confidence)

CPC Consumption Per Capita

The actual confidence of the people in the system is taken here as the average of the percentage values of the above three factors. Under those circumstances, the actual confidence will be $0 \leq \text{PCS} \leq 1$.

$$\text{PCS.K} = \frac{\text{UPCS.K} + \text{WPC.K} + \text{CEPC.K}}{\text{MPCS}} \qquad (84A)$$

PCS People's Confidence in System (confidence units)

UPCS UnemPloyed's Confidence System (confidence units)

CEPC Consumption Effect on People's Confidence (confidence units)

MPCS 300

The observed people's confidence in the system takes into account not only the actual or current state of the people, but also the past confidence states which obviously influence the present people's confidence. A smoothing equation is used:

$$\text{OPCS.K} = \text{OPCS.J} + (\text{DT})\,\frac{1}{\text{DOPC}}\,(\text{PCS.J} - \text{OPCS.J}) \qquad (85L)$$

Observed People's Confidence in System (confidence units)

PCS People's Confidence in System (confidence units)

DOPC Delay in Observing People's Confidence (months)

The above factor has a definite influence on the "conflicts" experienced by the city. By conflicts are meant all sorts of related factors which cause entrepreneurs to invest less or to invest somewhere other than in the city. Among these factors, the frequency of strikes, the lack of security in the city (robberies, violence, etc.), and the continuous pressures for new benefits and better wages seem to be the most important. Figure 17 represents the frequency of conflicts as a function of the observed people's confidence. The frequency of conflicts (FC) is inversely affected by the level of the people's confidence (OPCS). However, very large values of OPCS will not make the frequency of conflicts disappear; rather, they will cause them to approximate a minimum value, which represents the effects of other causative factors. On the other hand, when OPCS is decreasing, an increase in conflicts can be expected. This assumption makes the function convex from the origin.

FC.K = TABHL(TAFC, OPCS.K, 0, 1, 0.2) (86A)

| | |
|---|---|
| FC | Frequency of Conflicts (dimensionless) |
| OPCS | Observed People's Confidence in System (confidence units) |

The entrepreneurs' confidence in the system is assumed to be of two factors:

(1) A factor due to the frequency of conflicts:

ECS1.K = TABHL(TEC1, FC.K, 0, 100, 20) (87A)

| | |
|---|---|
| ECS1 | Entrepreneurs' Confidence in System (one) (confidence units) |
| FC | Frequency of Conflicts (dimensionless) |

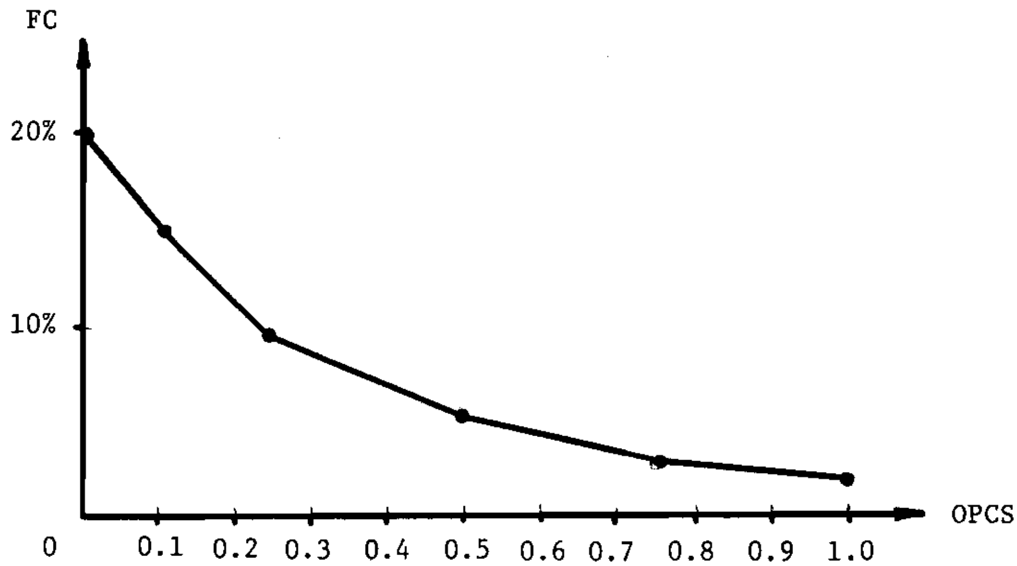



Fig. 17. Frequency of Conflicts

The kind of relationship between the two components shown in Figure 18, and its explanation will be omitted here.

(2) A factor due to the actual ratio of the observed inventories and the average consumption rate. This ratio will be called the stock factor ratio.

$$RSF.K = \frac{ACR.K}{OI.K} \tag{88A}$$

| | |
|---|---|
| ECS2.K | TABHL(TEC2, RSF.K, 0.8, 0.925, 0.025) |
| | (Ratio) Stock Factor (1/month) |
| ACR | Average Consumption Rate (units/month) |
| OI | Observed Inventory (units) |
| ECS2 | Entrepreneurs' Confidence in System (two) (confidence unit) |

The above ratio affects the second component of the entrepreneurs' confidence (ECS2). A large inventory with low sales will give a very low

RSF which influences (negatively) the entrepreneurs' confidence. Similarly, a low inventory with high sales will yield a large ratio and increase the entrepreneurs' confidence. The shape of the assumed function is represented in Figure 18.

The total entrepreneurs' confidence also is assumed to be the average of the percentage values of the above two factors.

$$ECS.K = \frac{ECS1.K + ECS2.K}{MECS} \tag{89A}$$

| | |
|---|---|
| ECS | Entrepreneurs' Confidence in System (confidence units) |
| ECS1 | Entrepreneurs' Confidence in System (confidence units) |
| ECS2 | Entrepreneurs' Confidence in System (two) (confidence units) |
| MECS | 200 |

The observed entrepreneurs' confidence in the system is represented by the following:

$$OECS.K = OECS.J + (DT)\frac{1}{DOEC}(ECS.J - OECS.J) \tag{90L}$$

| | |
|---|---|
| OECS | Observed Entrepreneurs' Confidence in System (confidence units) |
| ECS | Entrepreneurs' Confidence in System (confidence units) |
| DOEC | Delay in Observing Entrepreneurs' Confidence (months) |

The above factor will influence three variables of the production sector: the desired inventory to control per month (DITCM, equation 54A), the desired backlog to control per month (DBTCM, equation 55A), and the desired production by workers (DPRW, equation 66A). Its influence upon

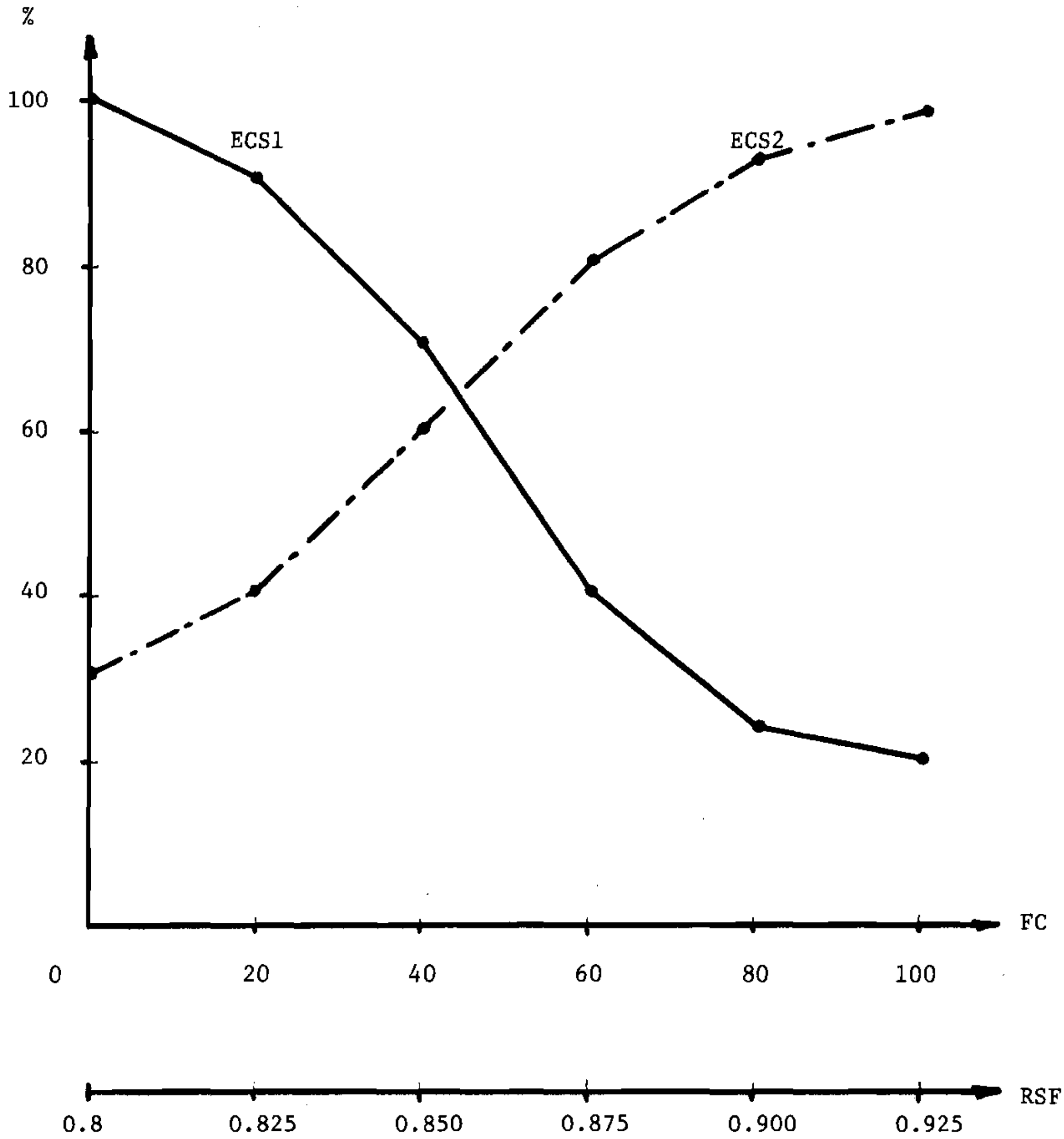



Fig. 18. Entrepreneur Confidence Functions

the first two factors is related to the fractional percentage of inventory or backlog to control per month (Fig. 19, curve FITC):

FITC.K - TABHL(TFIC, OECS.K, 0, 1, 0.2) (91A)

FITC Fraction of Inventory (or backlog) To Control per month (dimensionless)

OECS Observed Entrepreneurs' Confidence in System (confidence units)

Finally, the observed entrepreneurs' confidence influences the propensity (desire) to use workers; this is also a factor affecting the desired production by workers. This kind of relationship also is a table function (Fig. 19, curve PTUW) which assumed the following:

(a) There exists a value for OECS such that the propensity to use workers does not affect the desired production by workers (DPRW); in this case its value is one, and it can be considered a normal value for this factor if the system will perform in a steady-state condition. When PTUW = 1, OECS is assumed to be 0.3.

(b) For values of OECS $\leq$ 0.3, the assumed curve is concave (from the origin) and it also takes values less than one. This means that when the observed entrepreneurs' confidence is $\leq$ 0.3, the observed entrepreneurs are willing to use fewer people than under a normal situation.

(c) For values of OECS $\geq$ 0.3, the curve takes a convex form and PTUW $\geq$ 1. For these values of OECS, entrepreneurs would be willing to use more people than in the normal situation.

PTUW PTUW.K = TABHL(TPTU, OECS.K, 0, 1, 0.2) (92A)

PTUW Propensity to Use Workers (dimensionless)

OECS Observed Entrepreneurs' Confidence (confidence units)

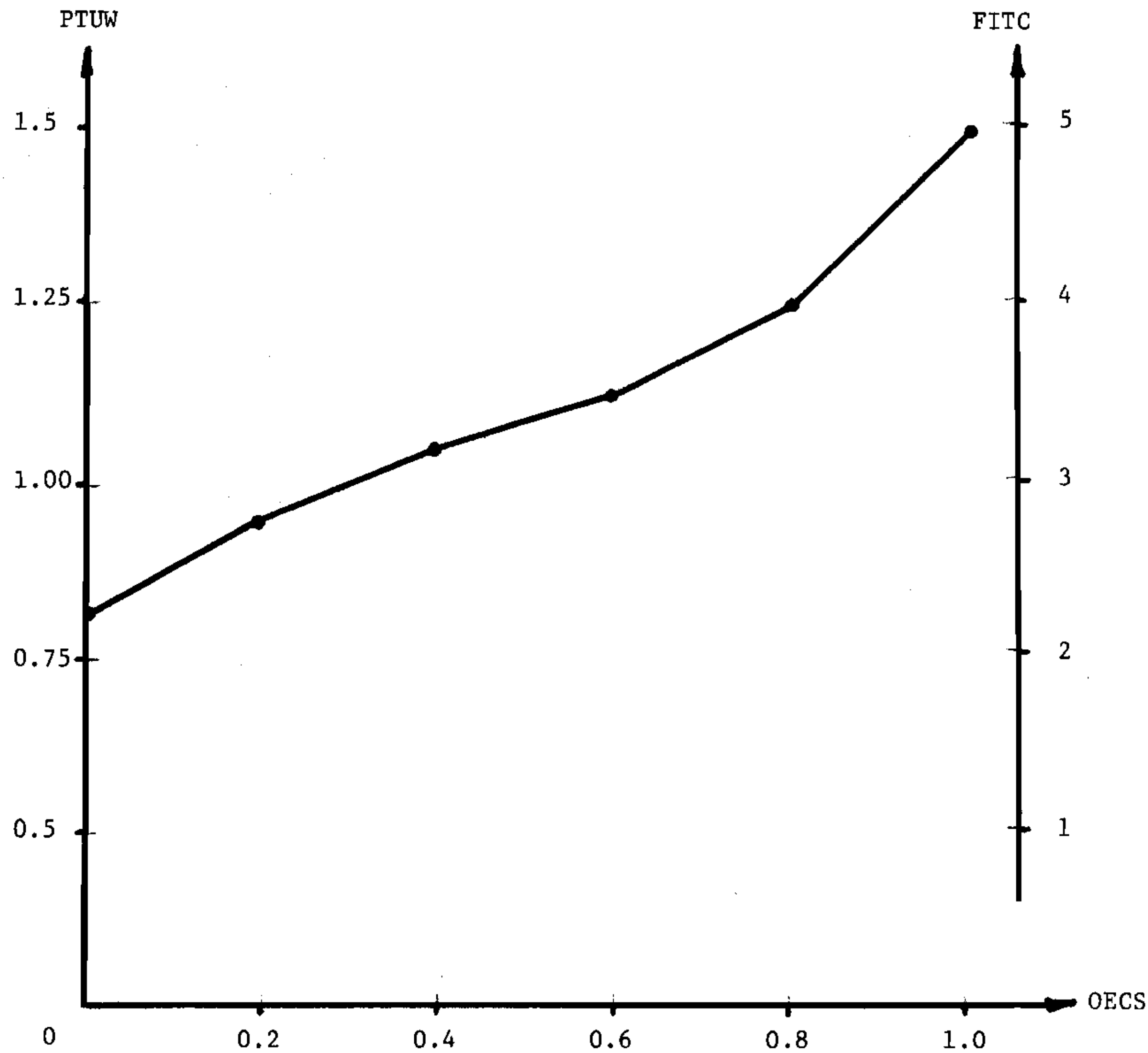



Fig. 19. Propensity to Use Workers and Fraction of Inventory to Control

## Beginning Values, Values of Parameters, and Input Functions

### Beginning Values

The equations representing the information feedback loops which create the dynamic patterns of behavior must be calculated cyclically at points in time defined by the solution interval DT. After a level is calculated, its effect upon the associated information network must be evaluated; this effect will influence the value of the rates of flow, which in turn will produce changes in the levels. This is a cycle process which does not have definite starting and ending points. However, in order to start the simulation, it is necessary to assign specific values to some of the variables. These values are the beginning values of the system and must be able to represent at least a version of the past history of the system and to define the forthcoming state of the variables.

By giving initial values to level variables, it is possible to calculate the auxiliary variables within the information network. This information makes it possible to calculate the rates of flow, which finally determine the new values for the levels. This is the way the DYNAMO language works. However, when rate variables are used in auxiliary or other rate equations, it is also necessary to give the initial value for the rate used. Otherwise, DYNAMO cannot be used to compute the auxiliary or related rate equation (5, p. 166).

Before attempting to describe the beginning values, it is appropriate to consider the probable behavior of the system as a related stable or unstable system, as well as to define the steady-state and transient conditions related to a system. The character of a system is stable if "it tends to return to its initial condition after being disturbed" (5, p. 51) and if this original disturbance declines and vanishes. On the other hand, a system is unstable if the original disturbance is amplified so that the pattern shown grows or produces oscillations of increasing amplitude. As in the actual system being modeled, the main variable to be focused upon is the increasing (although oscillating) unemployment, it may be assumed that the interacting feedbacks will create a growth pattern which will cause the system to be unstable.

Systems also can be under a steady-state or transient condition. A system is in a steady state if the pattern shown is periodic with time and the nature of the oscillations is the same. However, the system is under a transient condition when "the character of the system changes with time" (5, p. 51) and its response is "one-time and cannot repeat." If the initial condition of a system is a transient state, one of two things can happen: (1) if the system is stable, it finally will progress to a steady state, and (2) if the system is unstable, it will be forever under a transient, unstable growth process.

Although the above definitions seem to be precise, it is difficult in many socioeconomic situations to make a clear distinction as to the actual condition of the system. This seems to be the case for the unemployment problem in a developing city. How can we be certain that unemployment will continue growing for an extended period and that it will not reach an oscillating steady state after some longer period of time? For this reason we have preferred to start the system by using the actual date offered by the known statistics. Unfortunately, some of the levels shown in the model were not analyzed in those statistics, and the same is true for some of the beginning values needed for rate variables. In these cases, the modeler assumed values based upon his judgment, supported by interviews with people who had lived in Bogota.

Table 1 gives the initial conditions for the variables related to the labor sector.

Table 1. Beginning Values for the Labor Sector

| Name | Symbol | | Initial Condition | Dimension | Equation | Reference Source |
|---|---|---|---|---|---|---|
| Non-Workers | NW | = | 56,000 | men | 1L | (2); (3); (18)* |
| Training Workers | TW | = | 10,000 | men | 2L | assumed |
| Production Workers | PWO | = | 700,000 | men | 4L | (2); (3); (18)* |
| Observed Un-employment Hiring Rate | OU | = | 0.08 | - | 26L | assumed |
| Hiring Rate | HR | = | 1,000 | men/month | 14R | assumed |
| Intended Desires for Workers | IDWO | = | PWO | men | 7L | assumed |
| Intended Hiring of New Workers | IHNW | = | 0 | men | 13L | assumed |
| Intended Firing of Workers | IFW | = | 0 | men | 17L | assumed |

*Value estimated from references

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In the above table, it has been assumed that the initial value of intended desires for workers (IDWO) is equal to the actual number of production workers (PWO): IDWO = PWO.

Table 2. Beginning Values for the Salary Sector

| Name | Symbol | | Initial Condition | Dimension | Related Equation | Reference Source |
|---|---|---|---|---|---|---|
| Nominal Salary | NS | = | 1,500 | \$/men-month | 20L | assumed |
| Extra Salary Coming | ESCO | = | 100 | \$/men-month | 21L | assumed |
| Nominal Salary Rate | NSR | = | 5 | \$/men-month | 38R | assumed |
| Average Pressures to Increase Salaries | APIS | = | 0.16 | - | 34L | calculated from previous values |

Table 3. Initial Conditions for the Production and Consumption Sector

| Name | Symbol | | Initial Condition | Dimension | Equation |
|---|---|---|---|---|---|
| Average Consumption Rate | ACR | = | 17.6E8 | units/month | 47L |
| Observed Inventory | OI | = | (PDI)(ACR) | units | 48L |
| Inventory | INV | = | OI | units | 43L |
| Observed Desired Production | ODPR | = | ACR | units/month | 58L |
| Backlog of Orders | BOR | = | ACR | units | 56L |
| Goods in Process | GIP | = | ACR | units | 41L |
| Production Rate | PRR | = | GIP/DIR | units/month | 64R |

- - - - - - -

Note: All values have been assumed; 17.6E8 = $17.6 \times 10^8$

Table 4. Beginning Values for the Labor-Saving Techniques Sector

| Name | Symbol | | Initial Condition | Dimension | Related Equation |
|---|---|---|---|---|---|
| Labor-Saving Techniques | LST | = | 65,000 | capital units | 68L |
| Labor-Saving Techniques in Transit | LSTT | = | 0 | capital units | 67L |
| Intended Discharge of Labor-Saving Techniques | IDLS | = | 0 | capital units | 76L |
| Intended New Labor-Saving Techniques | INLS | = | 0 | capital units | 75L |
| Labor-Saving In-Rate | LSIR | = | 0 | capital units/ month | 77R |
| Observed Desires for Labor Saving | LDLS | = | LST | capital units | 70L |

Note: All values are assumed.

\- - - - - - -

Table 5. Beginning Values for the People's and Entrepreneurs' Confidence Sectors

| Name | Symbol | | Initial Condition | Dimension | Related Equation |
|---|---|---|---|---|---|
| Observed People's Confidence System | OPCS | = | 0.8 | per cent | 85L |
| Observed Entrepreneurs' Confidence in System | OECS | = | 0.9 | per cent | 90L |

Note: All values are assumed.

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Parameters of the System

The selection of the parameter values which follows may seem arbitrary and illogical from a statistical point of view. Most of them come from subjective judgments of the modeler, supported to a large extent by verbal descriptions of people who have lived in some Latin-American cities and by news reports from those countries (newspapers, magazines, etc.). The values for parameters have been selected in this way mainly for two reasons: First, statistics from which we can obtain all the information needed about Bogota do not exist. The selected values could be considered as hypotheses to be accepted or rejected for an appropriate statistical approach, but this is out of the scope of the present research. The second reason, and most important, deals with the character of industrial dynamics: the pattern of behavior of a model must be created largely by the information feedback loops which exist in any system, not by the set of values selected for parameters and even less by the input functions selected. Furthermore, when parameter values are selected reasonably, small changes (within a reasonable range) are not so sensitive to the behavior of most socioeconomic systems (5, p. 171). However, this does not exclude the possibility that a model, not the actual system, may be sensitive to a small number of parameters. In such case, statistical support of their values could be attempted; if further runs of the model show that these revised parameters are still sensitive, it could be that we have been overlooking an important source of variation within the model, and it would be preferable to redesign the model so as to incorporate those parameters as variables of the system (5, p. 172).

Table 6. Parameters Related to the Labor Sector

| Name | Symbol | Units | Related Equation |
|---|---|---|---|
| Delay in Filling Jobs | DFJ = 1 | months | 14R |
| Delay in Firing Rate | DFR = 2 | months | 18R |
| Delay in Training | DTR = 3 | months | 3R |
| Delay in Hiring New People | DHN = 3 | months | 13L |
| Delay in Firing Workers | DFW = 3 | months | 17L |
| Delay for Desired Workers | DLDW = 2 | months | 7L |
| Delay in Observing Unemployment | DOU - 1 | months | 26L |
| Maximum Percent of Workers to Fire | PWRF = 0.8 | - | 15A |
| Maximum Percent of People to Hire | PNRH = 0.8 | - | 11A |

Table 7. Parameters Related to the Salary Sector

| Name | Symbol | Dimension | Related Equation |
|---|---|---|---|
| Desired Standard of Living | DESL = 600 | $/man/month | 31A |
| Delay in Average Pressures | DAP = 2 | months | 39L |
| Auxiliary for Testing Sensitivity | AFS = 0.2 | - | 36A |
| Delay for Extra Salary Coming | DEFS = 3 | months | 22R |
| Percentage to Consumption | PCO = 0.9 | - | 39A |

Table 8. Parameters Related to the Production and Consumption Sector

| Name | Symbol | | | Dimension | Related Equation |
|---|---|---|---|---|---|
| Delay for Observed Desired Production | DODP | = | 3 | months | 58L |
| Average Production per Worker | APPW | = | 300 | unit/worker-month | 62A |
| Average Production per Labor Saving Unit | APLS | = | 30000 | unit/worker-month | 60A |
| Delay in Observing Inventories | DOI | = | 1 | months | 48L |
| Delay in Observing Average Consumption | DOAC | = | 2 | months | 47L |
| Delay for Depletion of Inventory | DCI | = | 0.25 | months | 45A |
| Constant Export Factor | CEXPF | = | 2 | - | 44A |
| Delay for Inventory Rate | DIR | = | 2 | months | 42R |
| Utilization Factor of Workers | UFW | = | 0.8 | - | 61A |
| Percentage for Desired Backlog Orders | PDO | = | 0.2 | - | 50A |
| Percentage for Desired Inventory | PDI | = | 1.2 | - | 49A |
| Auxiliary Testing Control Factor | CF | = | 0.3 | - | 53A |
| Percentage of Production for Workers | PNPRW | = | 0.1 | - | 65A |
| Fraction of Orders to Produce next month | FOTP | = | 1 | (1/month) | 57A |

Table 9. Parameters Related to the Labor-Saving Techniques

| Name | Symbol | Dimension | Related Equation |
|---|---|---|---|
| Delay in Labor Saving In-Rate | DLSI = 6 | months | 77R |
| Delay in Labor Saving Out-Rate | DLSO = 6 | months | 79R |
| Delay for Intended Labor-Saving Techniques | DILS = 9 | months | 75R |
| Delay for Discharge of Labor-Saving Techniques | DDLS = 4 | months | 76R |
| Delay for Labor-Saving Techniques in Transit | DLT = 2 | months | 78R |
| Delay for Desired Level of Labor Savings | DLDL = 3 | months | 70L |
| Utilization Factor of Labor-Saving Techniques | UFL = 1 | - | 53A |

Table 10. Parameters Related to the Confidence Sector

| Name | Symbol | Dimension | Related Equation |
|---|---|---|---|
| Delay in Observing People's Confidence | DOPC = 1 | months | 85L |
| Delay in Observing Entrepreneurs' Confidence | DOEC = 2 | months | 90L |
| Maximum Value of People's Confidence | MPCS = 300 | confidence units | 84A |
| Maximum Value of Entrepreneurs' Confidence | MECS = 200 | confidence units | 89A |

Assumed Table Functions. The table functions also are a kind of parameter of the system. However, although their values do not change directly with time, they are related to other variables of the system.

The table functions of the system were explained in the previous section. Here, we must define numerically the values for this special type of function.

| | |
|---|---|
| (a) | MPIS.K = TABHL(TPIS,PCW.K, 0, 1, 0.1) (equation 25A) |
| MPIS | Maximum Percentage to Increase Salary |
| PCW | Percentage (a fraction) of Cost of Workers |
| TPIS | 0.18/0.14/0.1/0.07/0.05/0.04/0.03/0.026/0.022/0.021/0.02 |
| (b) | VDIS.K = TABHL(TDIS, APIS.K, 0, 1, 0.1) (equation 35A) |
| VDIS | Variable Delay for Increasing Salaries (months) |
| APIS | Average Pressures for Increasing Salaries (number of units) |
| TDIS* | 10/7/5.2/4/3/2.4/1.8/1.5/1.3/1.2/1 |
| (c) | UPCS.K = TABHL(TUPC, OU.K, 0, 0.25, 0.05) (equation 80A) |
| UPCS | UnemPloyed's Confidence in System (confidence units) |
| OU | Observed Unemployment (number of units) |
| TUPC* | 100/90/60/32/24/20 |
| (d) | CEPC.K = TABHL(TCEP, CPC.K, 2700, 3200, 100) (equation 83A) |
| CEPC | Consumption Effect upon People's Confidence (confidence units) |
| CPC | Consumption Per Capita (units/men/month) |
| TCEP* | 20/40/68/84/96/100 |
| (e) | WPC.K = TABHL(TWPC, APIS.K, 0, 1, 0.2) (equation 81A) |

| | |
|---|---|
| WPC | Workers' Confidence (confidence units) |
| APIS | Average Pressures for Increasing Salaries |
| TWPC* | 100/90/76/44/28/20 |

| | |
|---|---|
| (f) | FC.K = TABHL(TAFC, OPCS.K, 0, 1, 0.2) (equation 86A) |
| FC | Frequency of Conflicts (%, dimensionless) |
| OPCS | Observed People's Confidence in System (confidence units) |
| TAFC* | 100/60/32/20/15/10 |

| | |
|---|---|
| (g) | ECS1.K = TABHL(TECI, FC.K, 0, 100, 20) (equation 87A) |
| ECSA | Entrepreneurs' Confidence in System (one) (confidence units) |
| FC | Frequency of Conflicts (%, dimensionless) |
| TEC1* | 100/90/70/40/24/20 |

| | |
|---|---|
| (h) | ECS2.K = TABHL(TEC2, RSF.K, 0.8, 0.925, 0.025) (equation 88A) |
| ECS2 | Entrepreneurs' Confidence in System (two) (confidence units) |
| RSF | (Ratio) Stock Factor (number of units) |
| TEC2* | 30/40/60/80/92/100 |

| | |
|---|---|
| (i) | PTUW.K = TABHL(TPTU, OECS.K, 0, 1, 0.2) (equation 92A) |
| PTUW | Propensity To Use Workers (dimensionless) |
| OECS | Observed Entrepreneurs' Confidence in System (confidence units) |
| TPTU* | .75/.95/1.05/1.15/1.25/1.5 |

| | |
|---|---|
| (j) | FITC.K = TABHL(TFIC, OECS.K, 0, 1, 0.2) (equation 91A) |

FITC Fraction of Inventory (and backlog) To Control (month)

OECS Observed Entrepreneurs' Confidence in System (confidence units)

TFIC* 2.2/2.8/3.2/3.5/4/4.8

Selected Value of DT

A first choice for DT is:

$$DT \leq \frac{1}{6}[\text{min. third order delay}]$$

$$DT \leq \frac{1}{6}\ (2\ \text{months}) = 0.33\ \text{months}$$

then: $DT = 0.25$ months

## Input Functions

When the boundaries of the system were established, the population pattern of the city and the price level were selected as two independent inputs of the system. Discussed at that time were population as a real input to the system and the weakness which the price level has when used in the model as an independent input affected by neither the variables of the system nor the population pattern.

The following equations deal with the two inputs selected, their initial conditions and the associated parameters (input conditions). The population and the labor force rate are taken here as two exponential functions.

PO.K = (PO)EXP(RT.K)

PO POpulation (men)

RT exponential variable. Rate of increase of population x Time

PO $2 \times 10^6$ initial condition

| | |
|---|---|
| RT.K | (RATA)(TIME.K) |
| RTL.K | RT.K/GFLF |
| RT | Exponential variable for population |
| RATA | RATe of increase of population per month |
| RTL | Exponential variable for labor force Rate |
| GFLF | Growth Factor for Labor Force |

In the above two equations, two constants are associated -- RATA and GFLF. The actual annual rate of increase of population (RATA) for Bogota has been estimated as 6.7 percent or $0.57 \times 10^{-2}$ per month, assuming a linear pattern for this factor (2, 3, 12). As the people currently being born will be entering into the labor force some years from now (in approximately 15 to 20 years on the average (3)), we can estimate the growth factor for the labor force (GFLF) as 1.4 times less than RATA.

RATA = 0.0057

GFLF = 1.4

As the model will be tested against a normal increase in the labor force rate (exponential shape) and also by observing the effect when the labor force is represented by a step function, we must define the following two variables:

LFR1.K = (SLF) EXP(RTL.K)

LFR2.K = (TF) STEP(JLF, 20)

The last equation is a jump step function for time = 20 months.

$$LFR2.K = \begin{cases} 0 & TIME.K < 20 \text{ months} \\ JLF & TIME.K \geq 20 \text{ months} \end{cases}$$

and the initial conditions are:

SLF = 0 or 5000 men/month (for different runs)

JLF = 5000 men/month at time $\geq$ 20

TF = 0 or 1 (for different runs)

Finally, the labor force rate:

LFR.K = LFR1.K + LFR2.K

For LFR as a step function: SLF = 0; TF = 1

For LFR as an exponential function: SLF = 5000; TF = 0.

The equations for the price level are:

(a) When the labor force rate is acting as an input:

P = 1 \$/unit, a constant

(b) When the labor force rate is considered as a constant:

P.K = input function (step)

P.K = STEP(JUP, 0)

JUP = 1.5 \$/unit

P = 1.0 \$/unit (initial condition)

# CHAPTER VI

## THE BEHAVIOR OF THE MODEL

The behavior of the model will be discussed under three situations:

(1) Population is constant (labor force rate is zero)

(2) The labor force rate is a step input function, and

(3) The price level is increased.

When the behavior of an industrial dynamic model is being studied, the analysis must be focused mainly on some of the most relevant qualitative aspects of the pattern, rather than on the quantitative factors resulting from the simulation (1; 5, p. 56). In the following pages will be discussed some of the most important patterns of behavior obtained. Qualitative aspects, such as stability, growth, time between peaks, and attenuation or amplification, will be the principal factors discussed.

Unfortunately, the model has results so complex that it is very time-consuming to deal with each one of the information feedback loops which have been the causes of the behavior. For this reason, only those which seem to be the most relevant to the behavior of the variables have been selected.

The attenuation or amplification factor has been taken as a percentage of the deviation from the mean value of the curve, as if it were obtained by a correlation study. However, it must be pointed out that as most of the variables incorporated in an industrial dynamic model may be highly correlated (5, p. 10; 27, p. 118), the correlation study could be out of the scope of this research.

Finally, we must point out the kind of relationships which will be used in order to explain the patterns of behavior. First, there exists a cause-effect relationship dealing with the set action-response. This means that a decision leads to an action which produces a determinate outcome (response). Second, and most important and crucial, is the cause-effect relationship dealing with the set feedback-pattern. In this case, an information feedback loop causes the pattern of behavior in which we are interested.

## Behavior of the Model When the Population Is a Constant

This section analyzes the behavior of the model when the rate of increase of population and the labor force rate are zero. In this case, the system itself is not receiving any kind of influence from its environment: new people are not entering into the labor force and the total population is also maintained constant. Although this is an unrealistic situation, it can reveal much information about the model with which we are dealing. If the model produces a growth pattern of behavior for the unemployment factor, our immediate conclusion would be that the increasing unemployment in the city is generated from "within," and not caused by an increasing labor force. In this case, the causes of high unemployment could be the governing policies and the general structure of the related feedbacks, and consequently, any corrective policy must not contain considerations of population or labor force control. Rather, they must consider a redesign of the production and reorder policies, the hiring and firing policies, and the use or discharge policies for equipment. On the other hand, if the model shows a goal-seeking system (negative feedback character), the conclusion reached would be that the labor force pattern and the increasing rate of population must exert influence somewhere in the model in such a way as to shift it from a negative feedback character into a positive one. This kind of shifting is common in complex socioeconomic systems (5a, p. 108). However, if after testing the model with a labor force rate different from zero (step function, exponential function, etc.), the model still persists with its negative feedback character, our conclusion would be that the model is not a representation of the real system.

Figures 20-25 represent the behavior of the model under the above input conditions. Their equations are:

| | | |
|---|---|---|
| RATA.K | $= 0$ | Rate of increase of population |
| LFR.KL | $= 0$ | Labor Force Rate |
| PO.K | $= 2 \times 10^6$ | Population |

As shown in those figures, the behavior of the model under this situation represents a goal-seeking system for the variables dealing with unemployment and people. However, the nominal salary pattern shows a growth process and the job supply presents a growing and oscillating unstable situation.

The above patterns are created by the information feedback loops represented in Figures 26-28. The growing nominal salary is caused by a positive feedback. The nominal salary rate (NSR) depends upon three factors: First, workers are always trying to put more pressures upon entrepreneurs for better salaries (PIS). This factor can make the

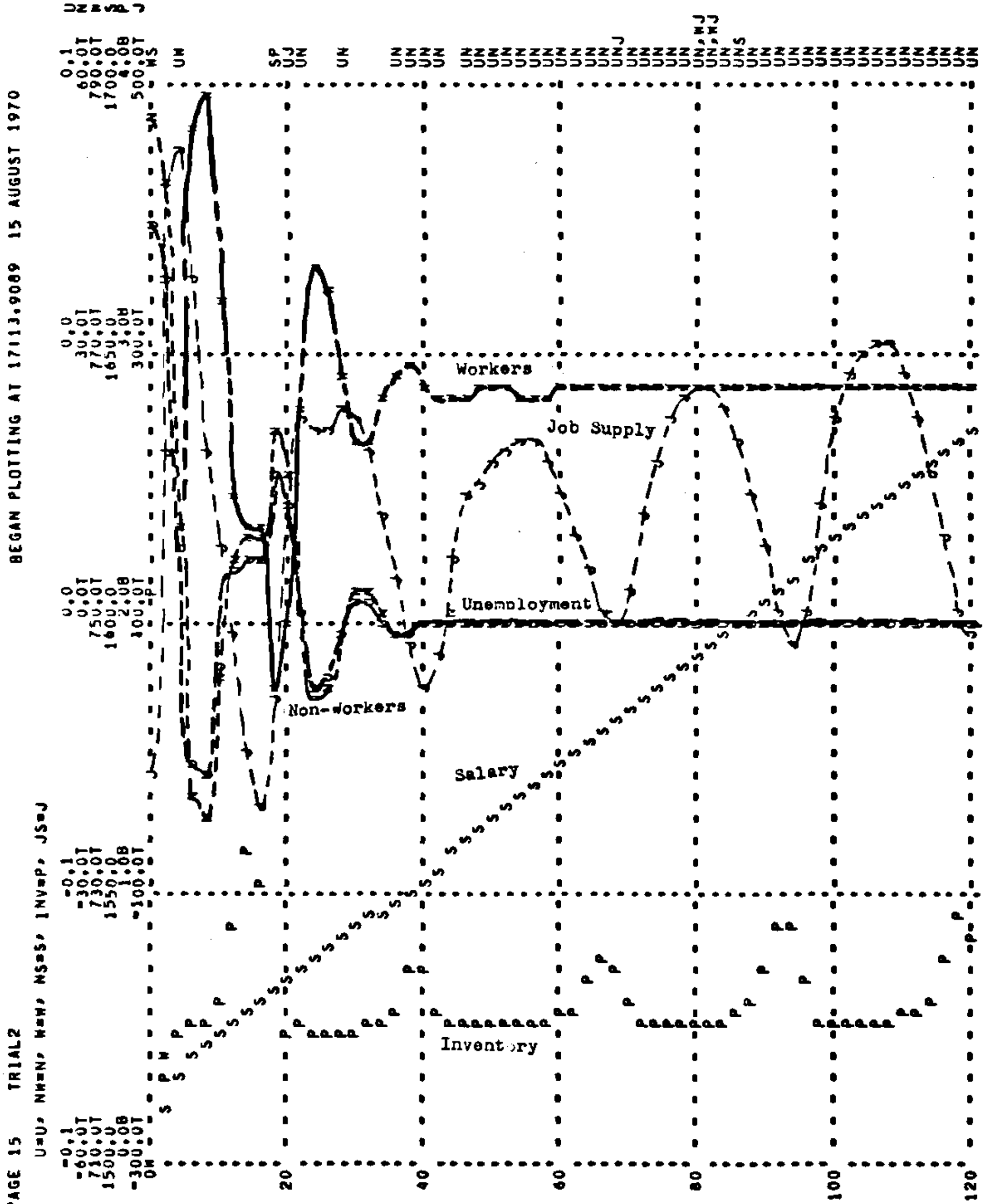


Fig. 20. Behavior of the Model When Population is a Constant

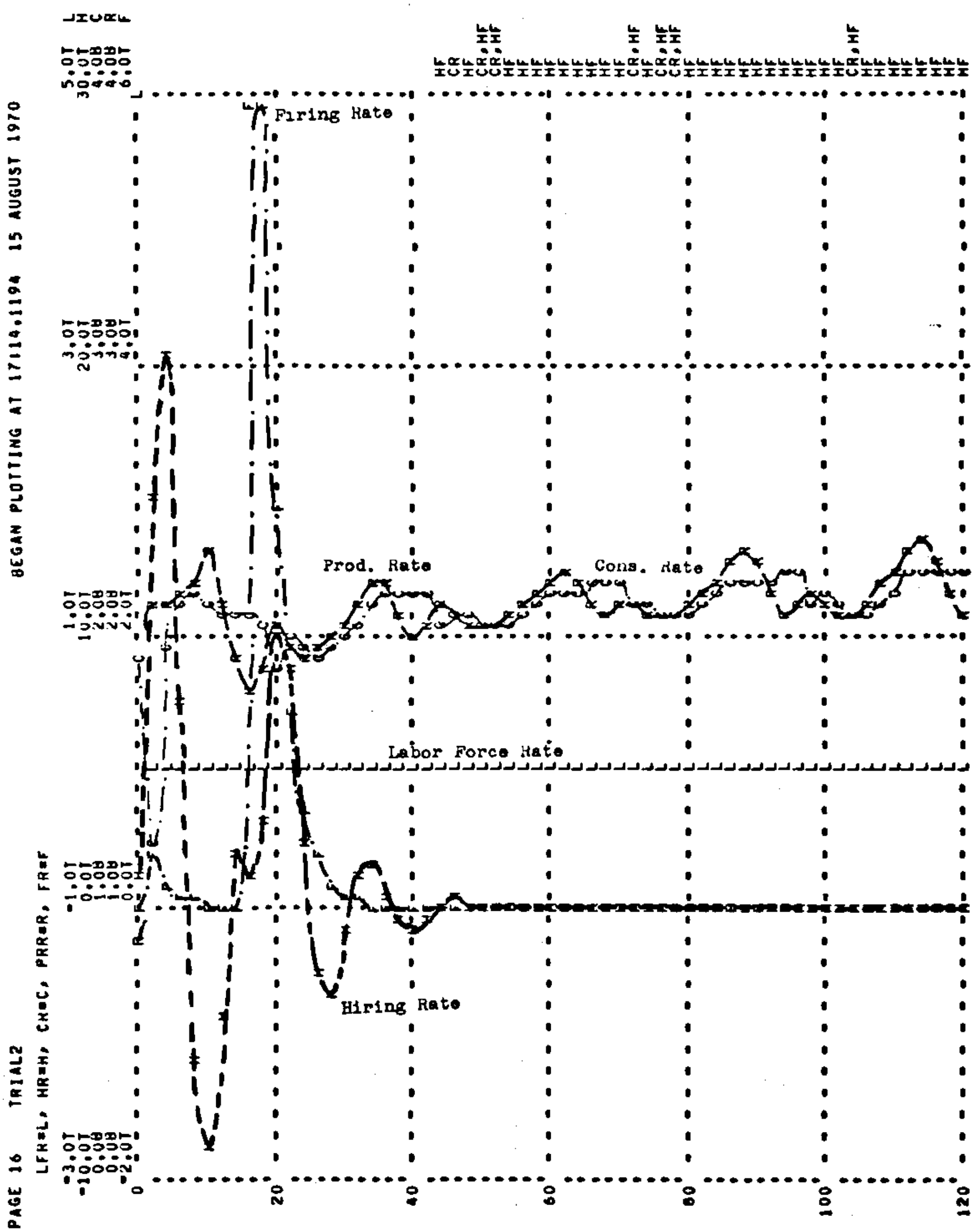


Fig. 21. Behavior of the Model When Population is a Constant

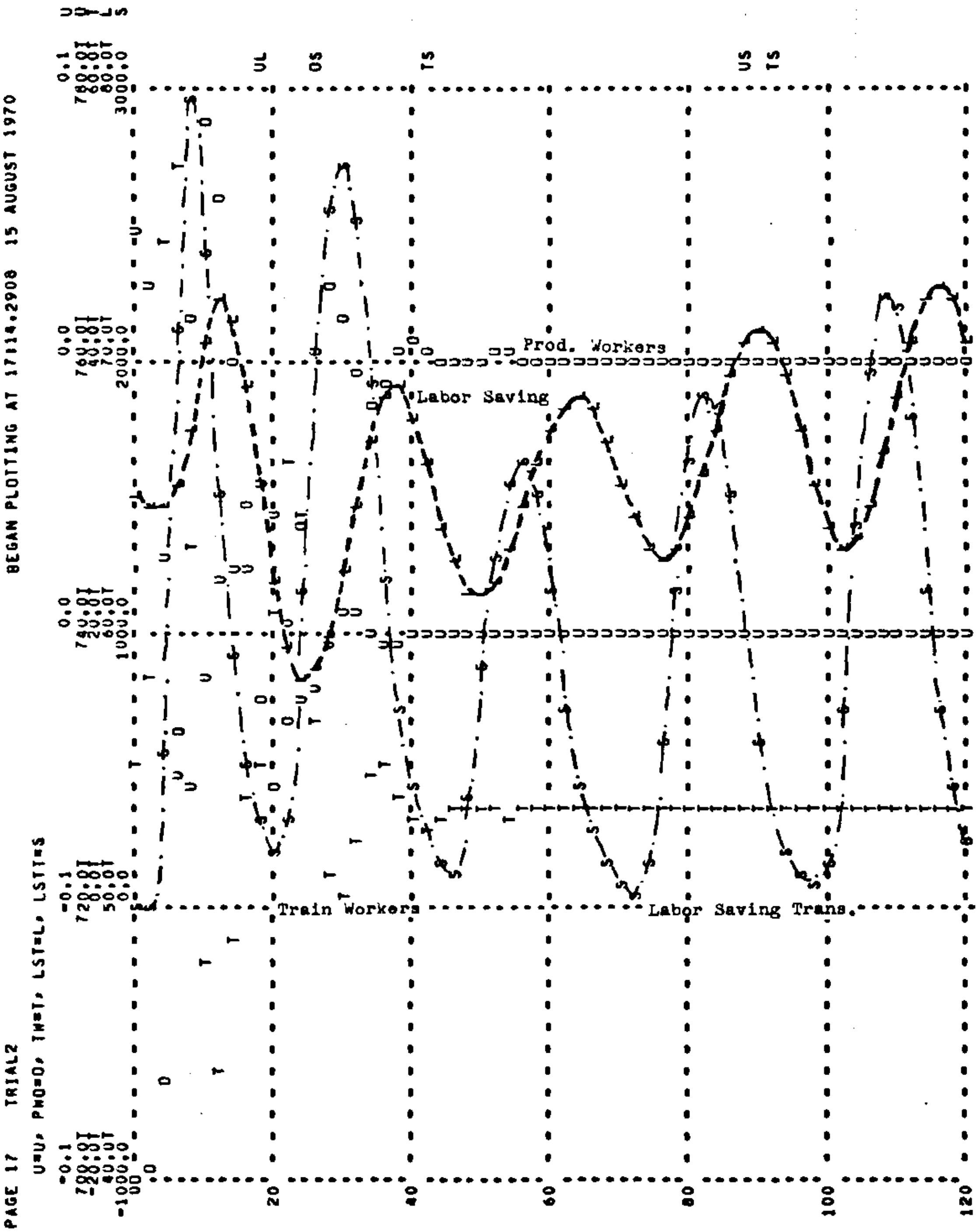


Fig. 22. Behavior of the Model When Population is a Constant

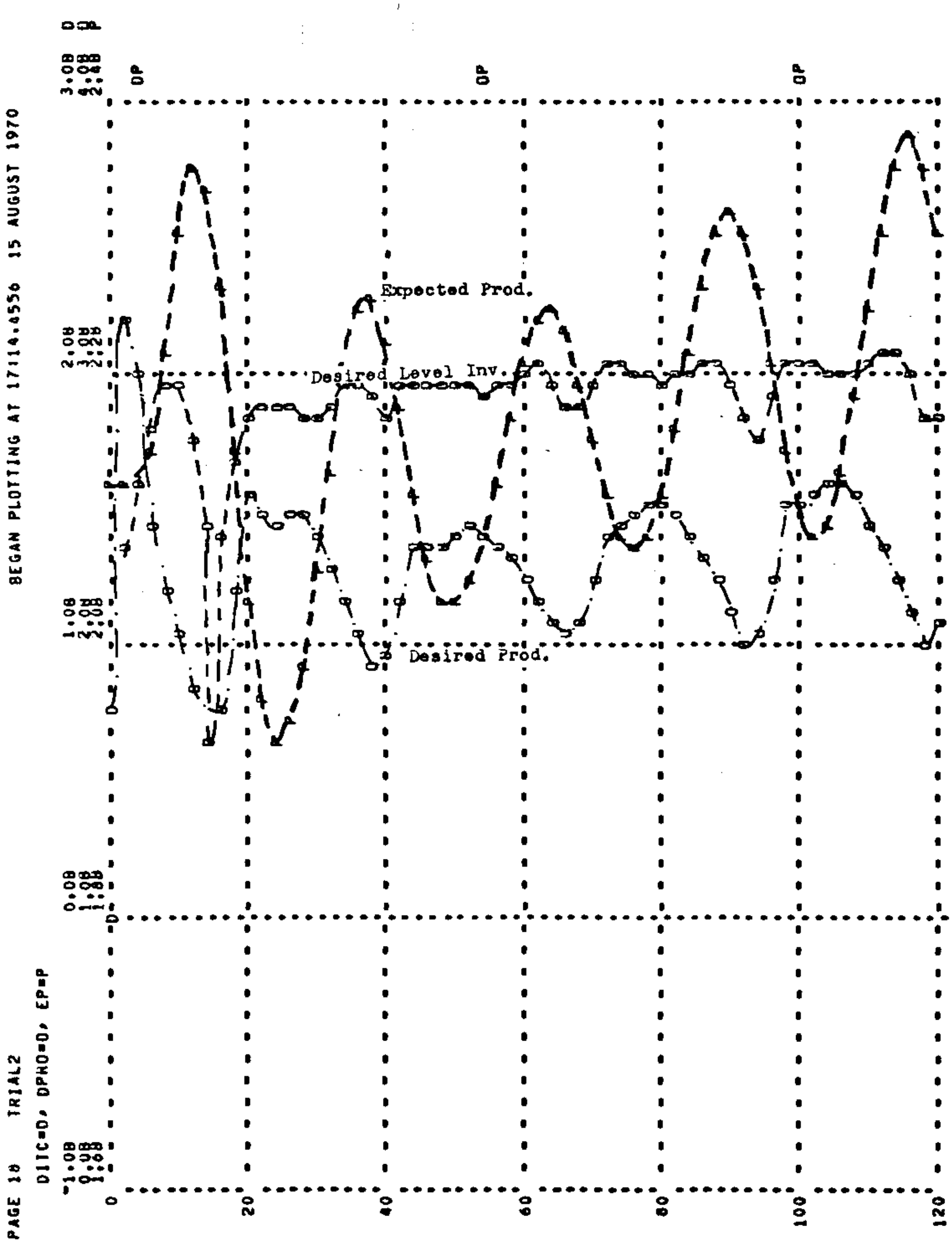


Fig. 23. Behavior of the Model When Population is a Constant

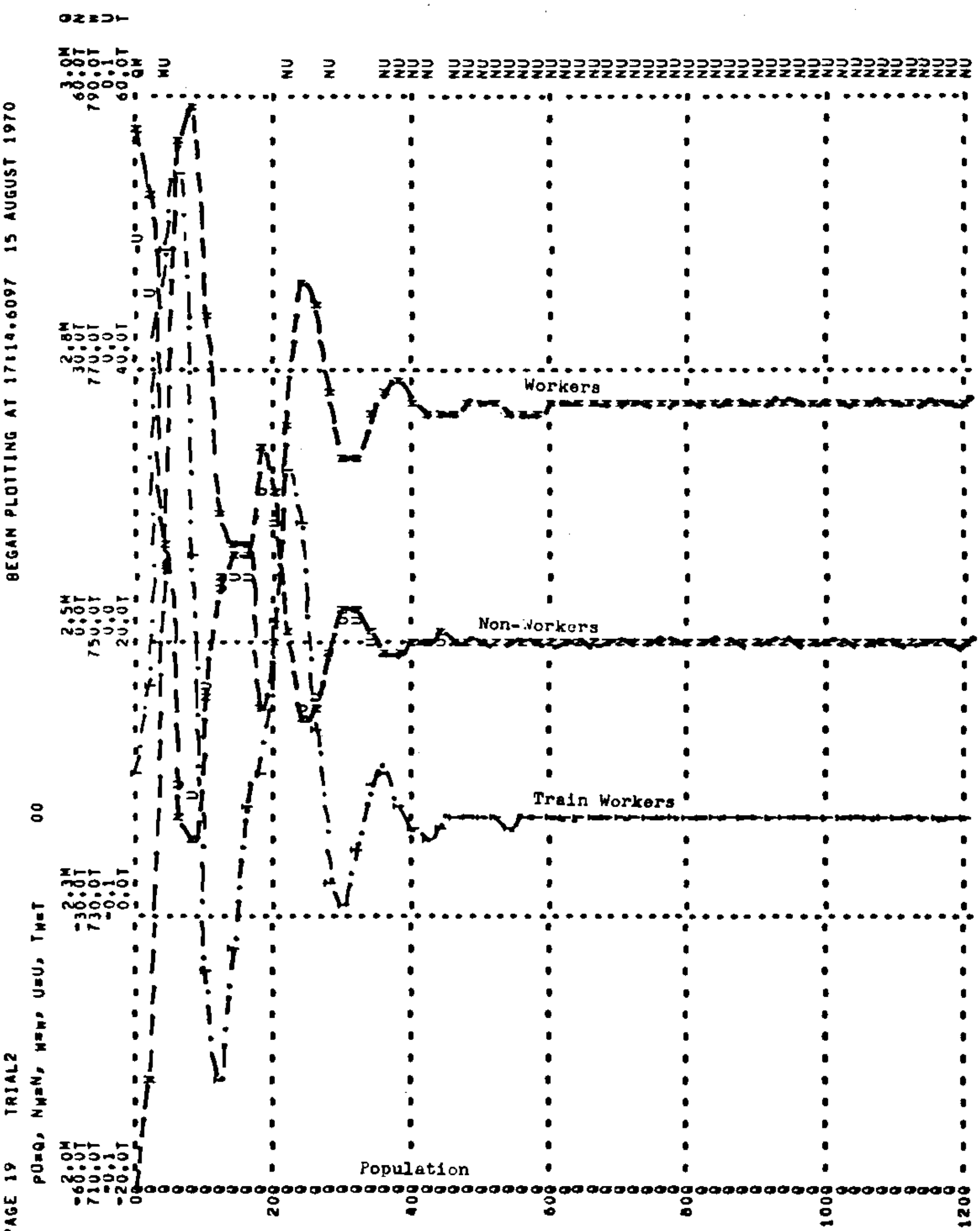


Fig. 24. Behavior of the Model When Population is a Constant

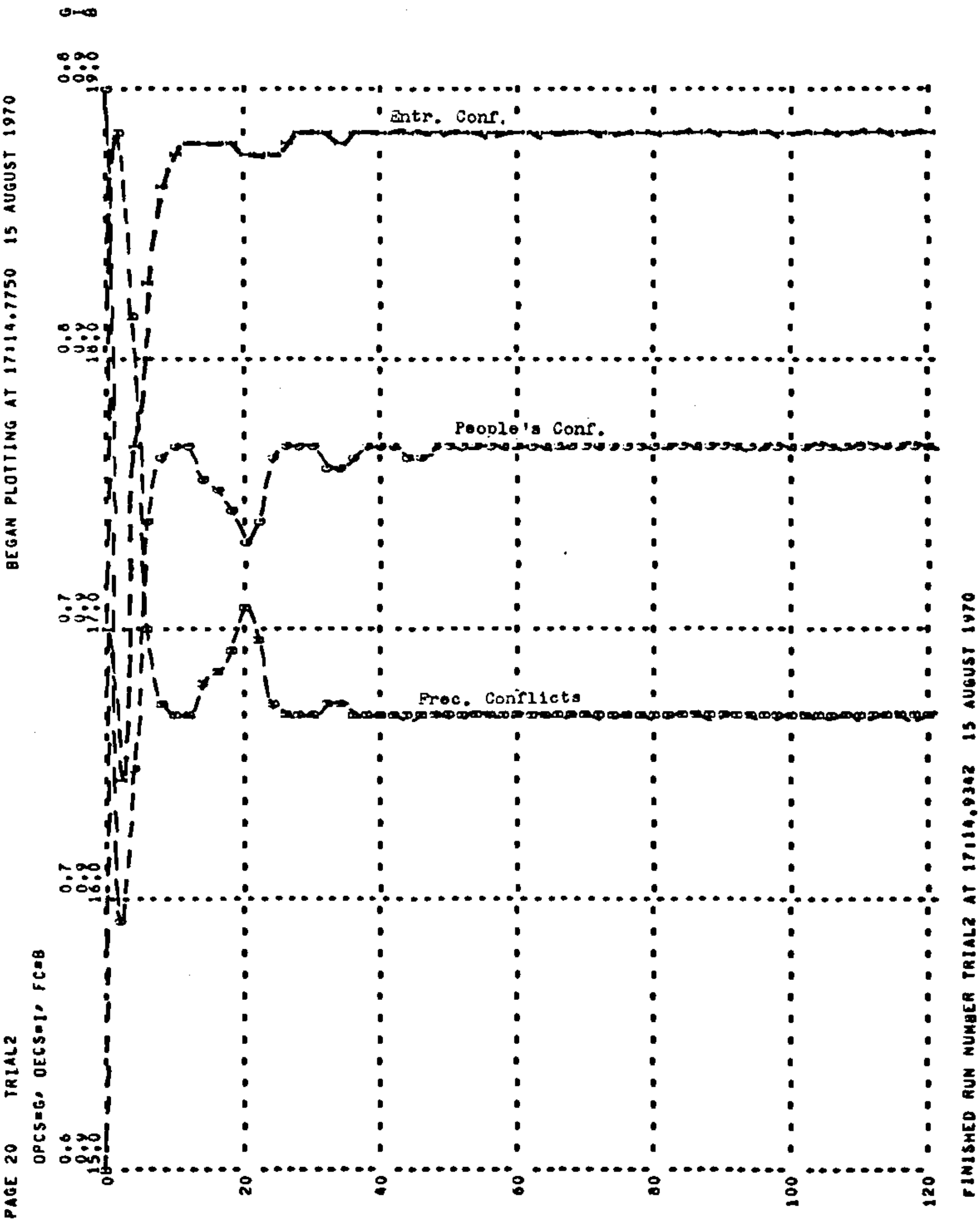


Fig. 25. Behavior of the Model When Population is a Constant

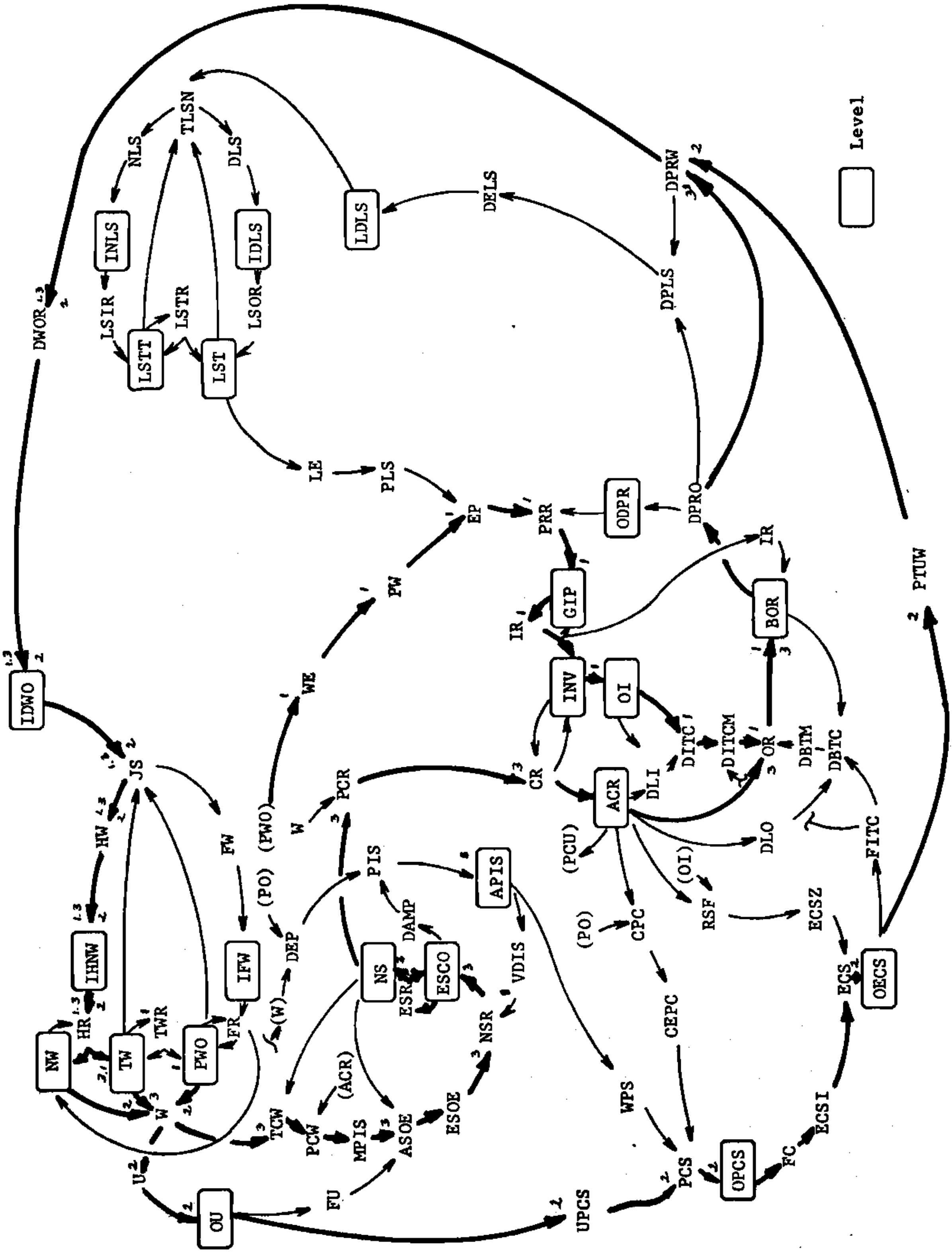


Fig. 26. Information Feedback Loops of the Model

variable delay for increasing salaries (VDIS) short enough so that the nominal salary rate increases. Second, an increase in workers has a diminishing effect upon unemployment. When fewer people are available for filling jobs, entrepreneurs are stimulated to offer even higher salaries. Last, a third factor has a counterbalancing effect on the other two: more workers increase the total cost of people. If the average sales per month are not so large, the effect is an increase in the percentage cost of workers (PCW), which makes entrepreneurs reluctant to increase the nominal salary rate further. However, more people working means more consumption (sales), which cancels this effect. The increasing nominal salary, combined with a larger number of workers, causes the consumption to increase (price level is a constant).

When entrepreneurs decide their reorder value for goods (and services), they mainly observe their average consumption. If this factor is high enough, the reorder decision will be high. Entrepreneurs also consider their expected production. If they are short in manpower (and/or equipment), they will intend to hire more people. Finally, more people working (less unemployment) leads to further increases in salary. This explains the growing nominal salary pattern (Fig. 26, path #3).

The workers (W), non-workers (NW), and unemployment (U) patterns (Fig. 20) represent a typical negative feedback behavior when the information loop contains more than two levels. The job supply (JS) reaches its first maximum point four months after the zero time, while the worker level (W) reaches its maximum value three months thereafter. The job supply determines the worker pattern until the 20th month. Just after this month, the job supply starts its oscillating unstable behavior, although the workers and non-workers patterns have already reached their steady-state condition. Table 11 gives the maximum points for the job supply workers, non-workers, and unemployment curves, and for the hiring and firing rate curves; the percentages shown represent the deviations from the mean steady-state value of the pattern. This factor represents the attenuation factor for the goal-seeking patterns and the amplification factor for the unstable oscillations of job supply.

Table 11. Attenuation of Variables in the Labor Sector

| | | | | | | |
|---|---|---|---|---|---|---|
| Workers (W) | Time (months) | 7 | 25 | 38 | 52 | 60 |
| | Value (max.) | 790,000 | 775,000 | 769,000 | 768,000 | 768,000 |
| | % | 2.97 | 0.96 | 0.13 | 0 | 0 |
| Non-Workers (NW) | Time (months) | 18 | 30 | 40 | | |
| | Value (max.) | 20,000 | 5,000 | 0 | | |
| | % | very large | very large | | | |
| Unemployment (U) | Time (months) | 18 | 30 | 40 | | |
| | Value (max.) | 0.025 | 0.0009 | 0 | | |
| | % | very large | very large | 0 | | |
| Job Supply (JS) | Time (months) | 4 | 30 | 56 | 80 | 106 |
| | Value (max.) | 450,000 | 250,000 | 240,000 | 280,000 | 310,00 |
| | % | 200 | 56 | 30 | 47 | 52 |
| Hiring Rate (HR) | Time (months) | 5 | 20 | 34 | 46 | 50 |
| | Value (max.) | 20,000 | 1,000 | 4,000 | 1,000 | 0 |
| | % | very large | very large | very large | very large | 0 |
| Firing Rate (FR) | Time (months) | 2 | 16 | 34 | | |
| | Value (max.) | 300 | 6,000 | 0 | | |
| | % | very large | very large | 0 | | |

The job supply factor reaches a maximum value four months after the simulation has already begun. This increasing job supply (JS) affects the intended hiring of new workers (IHNW), which makes the hiring rate (HR) increase and reach its maximum value by the 5th month. The positive values of HR cause the level of workers in transit (trainees, TW) to increase (Fig. 24), while the level of non-workers is decreasing. By the 7th month, the production workers are just receiving the maximum delayed effect of the training workers entering the production sector (Table 11). During this 7th month, the worker level (trainees and production workers) reaches a maximum value of 790,000 men, with a deviation of 2.97 percent from its mean value (approximately 768,000). When the job supply (JS) reaches its maximum value, the difference between the intended number of desired workers (IDWO) and the total number of workers (W) (Fig. 26) is also a maximum. However, when the hiring rate increases, new people are entering the training level, and the total number of workers (W) increases. This fact tends to reduce the above differences (JS), which eventually reaches a value of zero and shifts into a negative value. After some delays (IHNW and related), the hiring rate becomes zero, while the firing rate begins to increase and leads the worker level toward a minimum value by the 18th month (Table 11). Meanwhile, the non-worker level is receiving all the entering fired people and reaches a maximum by the 18th month (just when the number of workers is at a minimum; there is no flow of people into or out of the system).

The model contains many feedbacks which have caused the above behavior of the labor sector variables. Some of them are positive feedbacks, while others are negative. However, the character of the latter has dominated the system under the present situation.

During the first months of the simulation, the following positive feedback seems to have a strong influence: more workers lead to a higher consumption rate. When entrepreneurs perceive the increasing consumption, they will order more at factories. Under this situation, the backlog of orders (BOR) increases, as does the desired production (DPRO). This increasing value may tend to increase the job supply, which finally will cause the worker level to rise even more (feedback #3, Fig. 26). This feedback seems to rule the hiring rate (HR) during the first months (Fig. 21).

However, once the non-worker level has been depleted (6th month), the above feedback cannot govern the HR any longer. Rather, it is governed by the negative feedback NW-HR-NW shown in Figure 26. Under this situation, the hiring rate is only a small fraction of the non-worker rate. This explains the similar patterns of behavior of the non-worker rate and the hiring rate (Figs. 20 and 21). The above feedback is obviously a negative one: more non-workers lead to a higher hiring rate, which decreases the non-worker level.

Unemployment follows a pattern which is quite similar to the one exhibited by the non-worker level. However, it lags behind it; this effect is rather obvious, and it is due to the effect of the worker level, which is opposite to that of the non-worker level. Unemployment presents a time between peaks of approximately 20 months (two years) (Fig. 20).

An additional positive feedback may be interacting with the two feedbacks just explained. This loop is completed through the path dealing with the confidences of people and entrepreneurs (Fig. 26, path #2).

The decreasing unemployment has a "good" effect on the two confidence levels. Under this situation, entrepreneurs become willing to hire even more people, which gives unemployment a decreasing value. However, as the labor force is zero, the unemployment decreases so rapidly that it becomes a negative value (10th month) (an absurd situation) and starts oscillating around the zero value. In this case, this positive feedback has a gain less than one, which makes the loop behave as a negative feedback.

The above feedbacks seem to be the main causes of the unemployment behavior. Of course, there are many others affecting its pattern.

It is interesting to note the unstable oscillation of the job supply after the 40th month. Although this factor oscillates between positive values, the worker level remains unchanged. This is due to the fact that non-workers have become zero and the labor force rate is also zero. In this case, even though entrepreneurs would like to hire people, they cannot find anyone to hire. This situation is also a non-realistic one. The increasing oscillation of JS is a result of an amplification of the effects produced by the feedbacks which control the reorder and production rates. Under the present input situations, the intended number of desired workers (IDWO) has a strong oscillation which makes the job supply (JS) vary as shown in Figure 20.

The IDWO receives influences from the desired production (DPRO), which has an increasing osciallation behavior, as shown in Figure 23.

Table 12 presents the amplification factor of the main factors related to the consumption-production sector.

Table 12. Attenuation of Variables in the Production Sector

| | | | | | | |
|---|---|---|---|---|---|---|
| Inventory (INV) | Time (months) | 14 | 38 | 64 | 92 | 116 |
| | Value (max.) x $10^9$ | 1.3 | 0.7 | 0.75 | 0.85 | 0.86 |
| | % | 160 | 40 | 50 | 70 | 72 |
| Production Rate (PRR) | Time (months) | 12 | 36 | 62 | 86 | 116 |
| | Value (max.) x $10^9$ | 2.3 | 2.2 | 2.25 | 2.35 | 2.4 |
| | % | 9.6 | 4.8 | 4.6 | 6.7 | 6.6 |
| Consumption Rate (CR) | Time (months) | 8 | 36 | 70 | 94 | 110 |
| | Value (max.) x $10^9$ | 2.15 | 2.15 | 2.15 | 2.2 | 2.2 |
| | % | 8/5 | 2/4 | 2/4 | 4/5 | 4/5 |
| Desired Production or Backlog at Factories (DPRO = BOR) | Time (months) | 4 | 20 | 52 | 80 | 106 |
| | Value (max.) x $10^9$ | 3.1 | 2.1 | 2.08 | 2.1 | 2.1 |
| | % | 2.9 | 4.8 | 8.2 | 9.6 | 11 |
| Expected Production (EP) | Time (months) | 12 | 38 | 64 | 90 | 116 |
| | Value (max.) x $10^9$ | 2.35 | 2.25 | 2.23 | 2.3 | 2.35 |
| | % | 5.1 | 5.8 | 4.1 | 5.2 | 4.7 |

In the above table are shown only the largest peaks of the production pattern.

The production sector behaves as an increasing and oscillating system without much amplification. The patterns have been caused by many negative feedbacks and some positive ones. Inventories present a somewhat interesting pattern; after people have been hired, inventories start increasing and reach a maximum by the 14th month. The production rate reached its greatest value two months before, and by the 14th month is

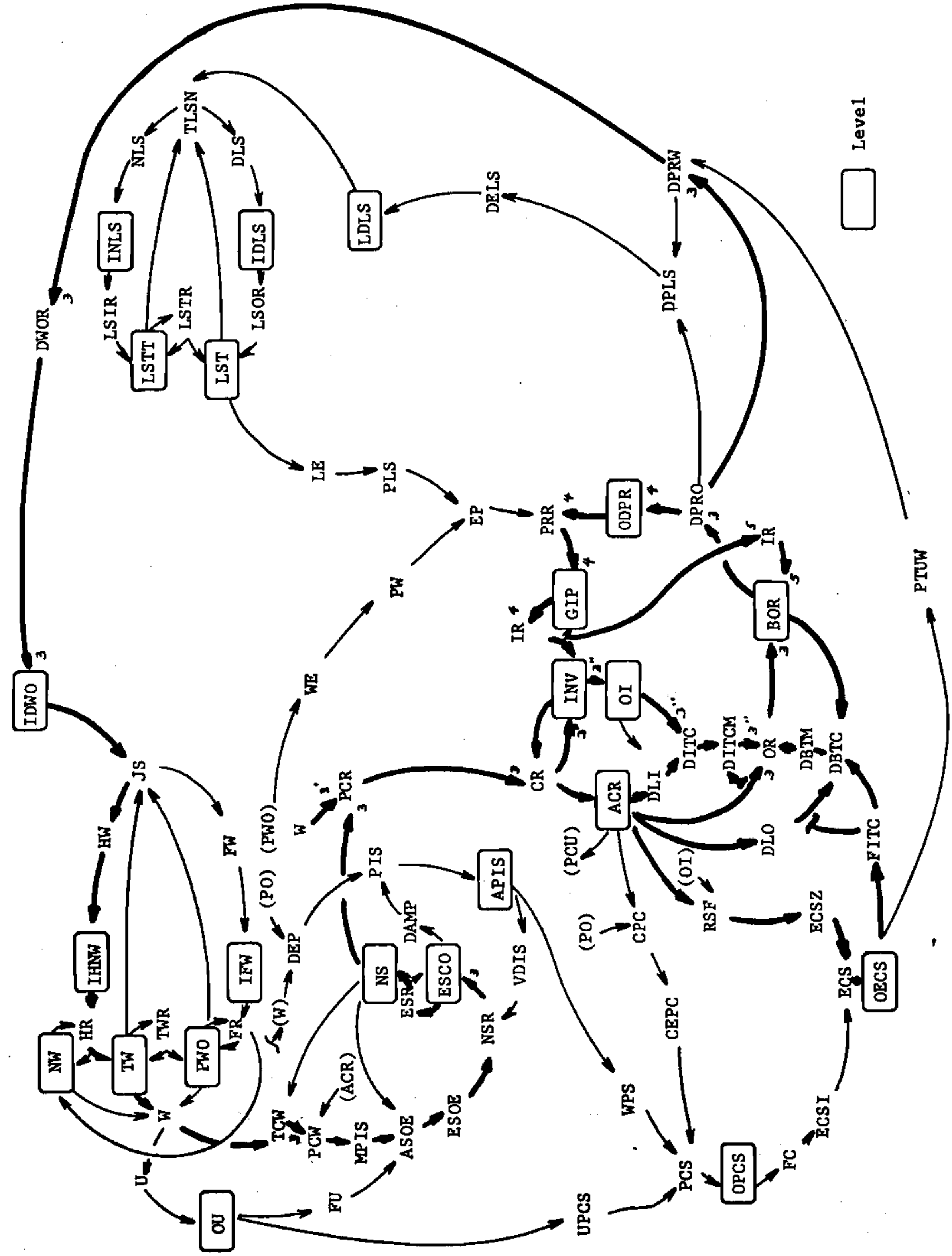


Fig. 27. Information Feedback Loops of the Model

decreasing (Fig. 21). This is due to the fact that inventories have been overstocked, surpassing the desired level of inventory (DLI). Under this situation, the order rate at backlog receives a counterbalance which shows the rate of increase of the backlog of orders at factories (BOR) (Figs. 23 and 27).

A similar pattern is followed by the orders for goods which have to fill the pipelines (DBTM, Fig. 27). In this case, the increasing backlog of orders (BOR = DPRO) has surpassed the desired level of orders in backlog (DLO); this affects the order rate (OR), which probably has begun to decrease.

The consumption rate pattern represents an increasing (but oscillating) curve. It increases because it belongs to the same positive feedback in which the increasing nominal salary lies (Fig. 27, feedback #3). Furthermore, consumption also is involved in another positive feedback (#$3^1$, Fig. 27) coming from the workers: the greater the number of workers, the higher the potential consumption rate and the larger the consumption rate. The increasing consumption rate causes the order rate at backlog to increase, thus increasing the backlog of orders (BOR) and the desired production (DPRO). The greater the desired production, the more the desired production by workers (DPRW), which increases the intended desires for workers even more (IDWO). Consequently, the job supply (JS) expands, with further gains in the number of workers, which will again make the consumption increase (Fig. 27, #$3^1$ -3).

Another important positive feedback dealing with the consumption rate is the following: high values of the consumption rate tend to deplete the inventories. When entrepreneurs observe their diminishing goods in stock, they will order more in order to avoid being out of stock. This situation also makes the desired production (DPRO) increase, with a further rise in the level of workers. This condition stimulates the consumption rate even more, and once again the inventory levels begin to fall (Fig. 27, #3" - 3).

The consumption rate has a limiting value. When its potential value is greater than a percentage of the inventory, the actual consumption rate is cut and is equal to the above percentage (Fig. 27, #3" - 3). This explains the step periods in the consumption pattern (Fig. 21).

The production pattern also is a growing and oscillating process. However, in this case, the pattern is produced only by negative feedbacks. Although this is rather an uncommon situation, there exist conditions in which negative feedbacks are coupled together in such a way that the result is a growing process. In this case, the growing pattern arises because of the conflict between the kinds of decisions governing the production rate and the consumption rate. The first rate is controlled by entrepreneurs, while the second is controlled mainly by people. On one side, the entrepreneur is trying to maintain a desired level of inventory (DLI); on the other, people are consuming in such a way that the impact is to deplete inventories. This is the kind of conflict in objectives which seems to be one of the causes for the increasing pattern of the production rate.

The production rate is controlled by four main negative feedbacks: (1) When the inventory is increasing, entrepreneurs tend to diminish their order rate. This has a negative effect upon the backlog of orders (BOR) and the desired production (DPRO). The decreasing desired

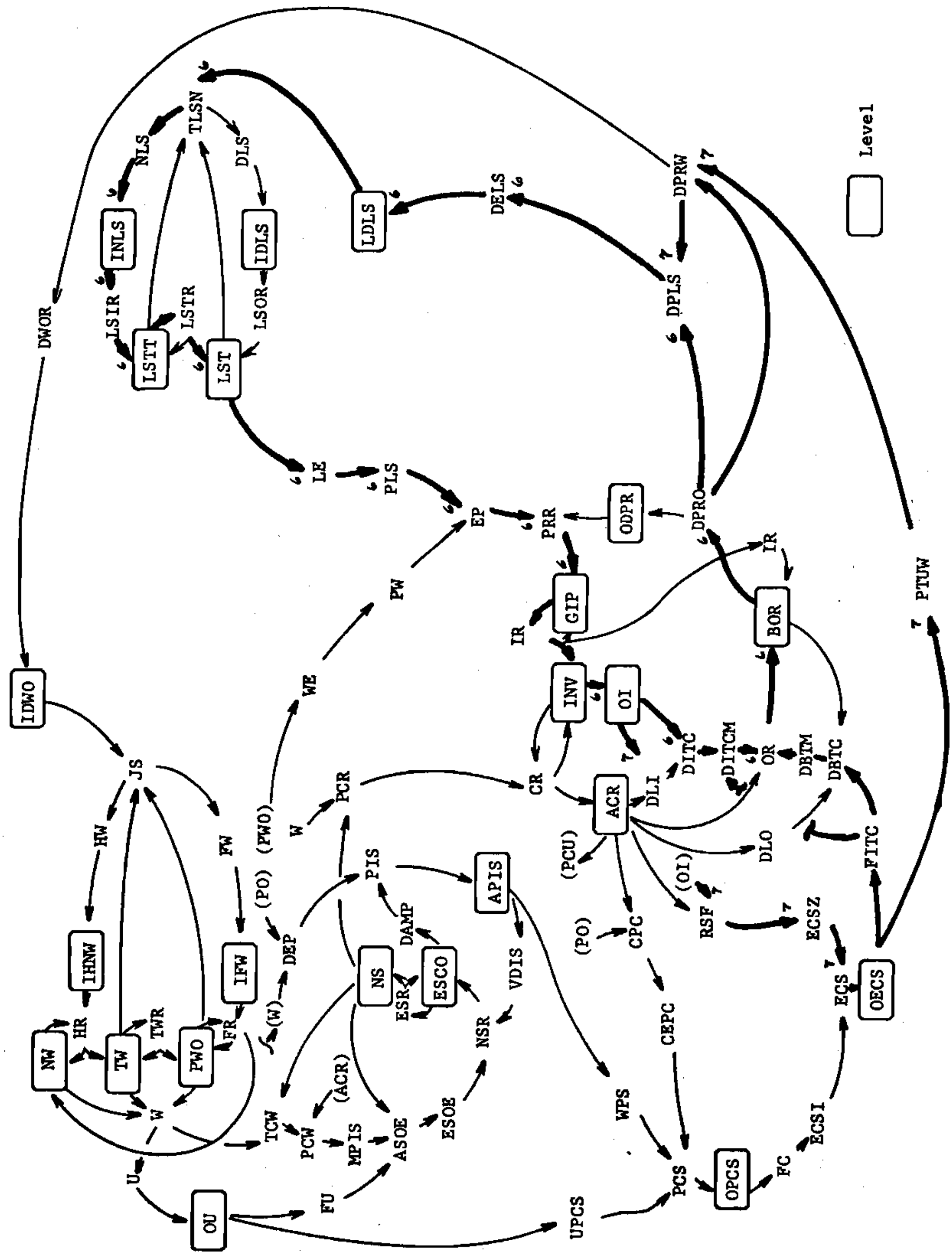


Fig. 28. Information Feedback Loops of the Model

production tends to decrease the production rate, which affects negatively the goods in process. The final result is a drop in the level of inventories (Fig. 27, path #3''-3-4). (2) When the goods in process (GIP) are increasing, the related delay (third order) defining the inventory in-rate (IR) makes the backlog of orders (BOR) decrease (Fig. 27, path #4-5-3). The lower this level is, the less the desired production (DPRO) and the lower the production rate, which causes the goods in process (GIP) to decrease. The other two negative loops are closed by the interactions of the labor sector and the labor-saving techniques (equipment) sector. Both of them interact, through the expected production: (3) More workers lead to greater expected production (EP), which eventually has a positive effect upon the production rate (if EP > DPRO). This increasing rate has the effect of making inventories increase, with a further decline in the backlog of orders (BOR) and in the desired production (DPRO) (Fig. 26, path #1). This finally tends to decrease the hiring rate (or to increase the firing rate), with a negative effect upon the level of workers. (4) This feedback is quite similar to (3). It is completed through the labor-saving techniques (Fig. 28, path #6).

The last feedback mentioned above is one of the principal causes of the pattern shown by the labor-saving techniques (Figs. 22 and 28). This feedback is the cause of the oscillating character. However, its tendency to grow must be explained by considering one additional positive feedback (Fig. 28, path #6.7). Before explaining it, we must consider some important assumptions. After the backlog of orders at factories (BOR) has changed, and similarly the desired production (DPRO), entrepreneurs have to allocate their budget between equipment and/or people. In many cases, entrepreneurs face a situation in which they can "substitute" equipment for people. If their confidence in the system is high, they can use relatively more people than equipment. Otherwise, they will try to import even more new capital-intensive machines. Furthermore, high inventories represent an unfortunate condition for business because their stock factor (RSF) is so high that entrepreneurs' confidence is decreased, thus causing them to invest less. However, in developing cities (such as Bogota), entrepreneurs are always interested in buying capital-intensive equipment, for two principal reasons: (1) Their products must be competitive with foreign ones. Although it may seem rather extraneous to relate this fact with the use of more labor-substitute quipment, the fact is that developing countries (such as Colombia) have not developed a competitive production technique based mainly on the use of more labor; (2) Developing countries frequently impose strong controls upon highly capital-intensive imports. This makes the delays in receiving equipment very long. The above two situations make entrepreneurs more aware of their future needs for equipment, even during periods of low confidence. If such is the case, entrepreneurs prefer not to invest in facilities that will require the use of more people, but rather, desire to mechanize their production to a greater extent than at present.

The related positive feedback is closed in the following way: An increasing inventory leads to a high stock factor (RSF) (Fig. 28, path #6-7), which decreases the entrepreneurs' confidence. This situation makes them use fewer people and invest more in labor-saving techniques. In this case, the total number of labor-saving techniques (TLSN) increases and augments the labor-saving technique level (LST). The larger this value is, the greater the expected production, which eventually leads to a higher production rate and to a higher inventory.

Finally, Figure 25 shows the behavior of the two confidence factors. Their analysis will be omitted here.

## Behavior of the Model under a Step Increase in the Labor Force

In this section is presented the behavior of the system when the test input is a step increase in the labor force. This kind of input represents a sudden disturbance in which an old constant labor force rate is changed to a new value that is then held constant. Although the step function is a non-realistic pattern for the labor force, it is one of the most useful tests when studying the dynamic behavior of a system. A step function contains, in principle, an infinite band of component frequencies (5, p. 172). This fact allows the model to show some of its internal characteristics. It can operate as a filter for some of the frequencies or can behave as an amplification system for others. Furthermore, if the system has oscillatory behavior, the model will display its natural frequency; if it has any cumulative tendency, it will exhibit sustained growth or decline.

The equations needed for generating a step increase in the labor force are the following:

JUMP.K = STEP(JLF, 20)

LFR.K = (TF)(JUMP.K)

LFR Labor Force Rate (men/month)

TF (0 or 1). For a step increase = 1

JLF 5000 men/month

The first equation indicates the following:

if TIME.K $\leq$ 20 months, JUMP.K = 0

if TIME.K > 20 months, JUMP.K = 5000

It must be remembered that under this test input, the population and the price level also are maintained constant.

$$\text{PO.K} = 2 \times 10^6 \text{ men}$$

$$\text{RATA.K} = 0$$

$$\text{P.K} = 1 \text{ \$/unit}$$

The behavior of the model under the labor force step is represented in Figures 29-34. During the first 60 months, the model shows a negative (oscillating) behavior for some of the variables. However, after this month, the model starts exhibiting a growth tendency as well as an unstable, oscillatory behavior. This means that some of the negative feedbacks shift in character into positive loops after the 60th month. This shift in behavior is not uncommon in many complex socioeconomic systems. Many of the loops are coupled together, and their interaction may set the gain of some of the positive loops into less than one. Under this situation, the positive feedback acts as a negative one. In other situations, two negative loops may be affected by other loops in such a way that they start their behavior in a positive way.

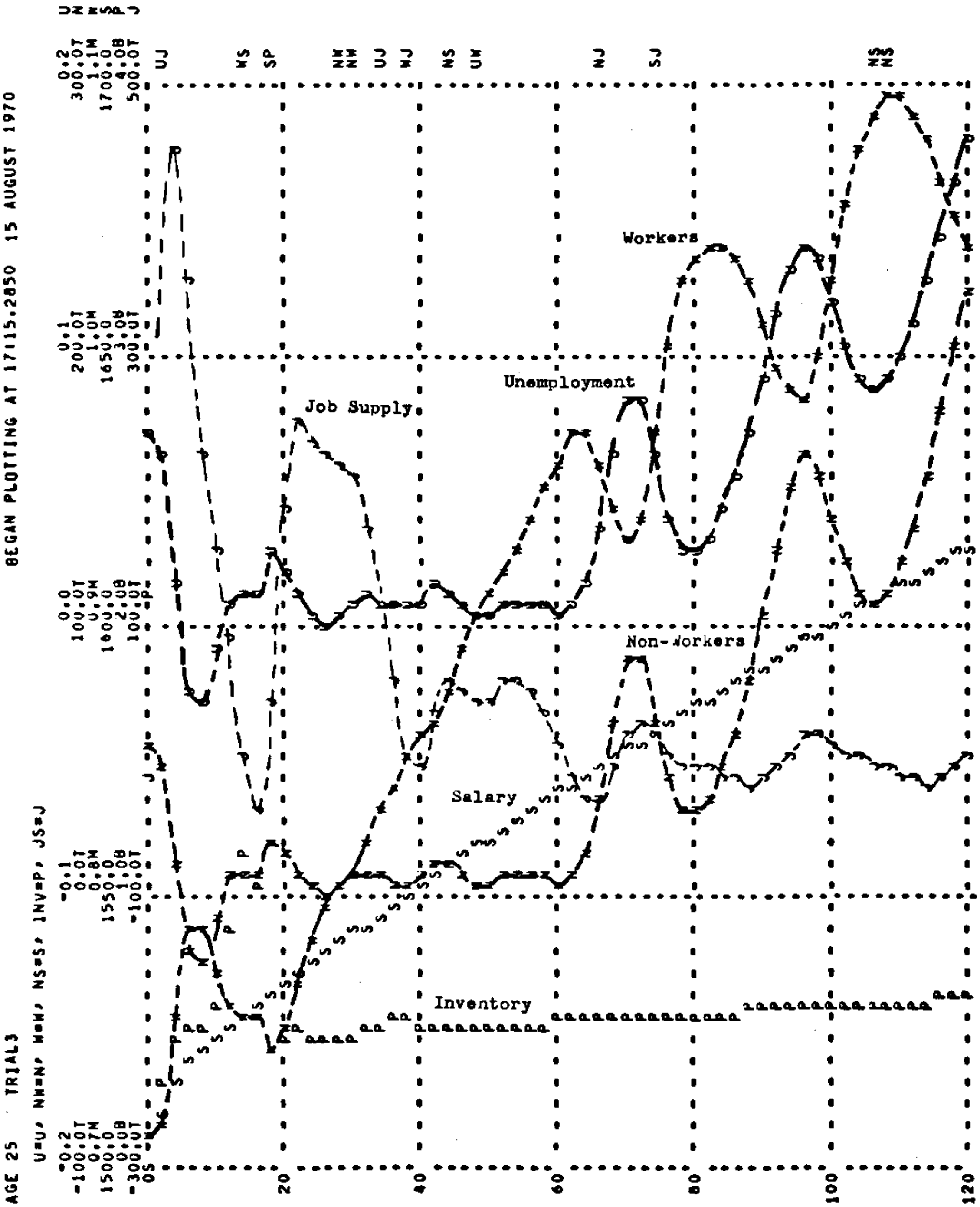


Fig. 29. Behavior of the Model Under a Step Increase in the Labor Force Rate

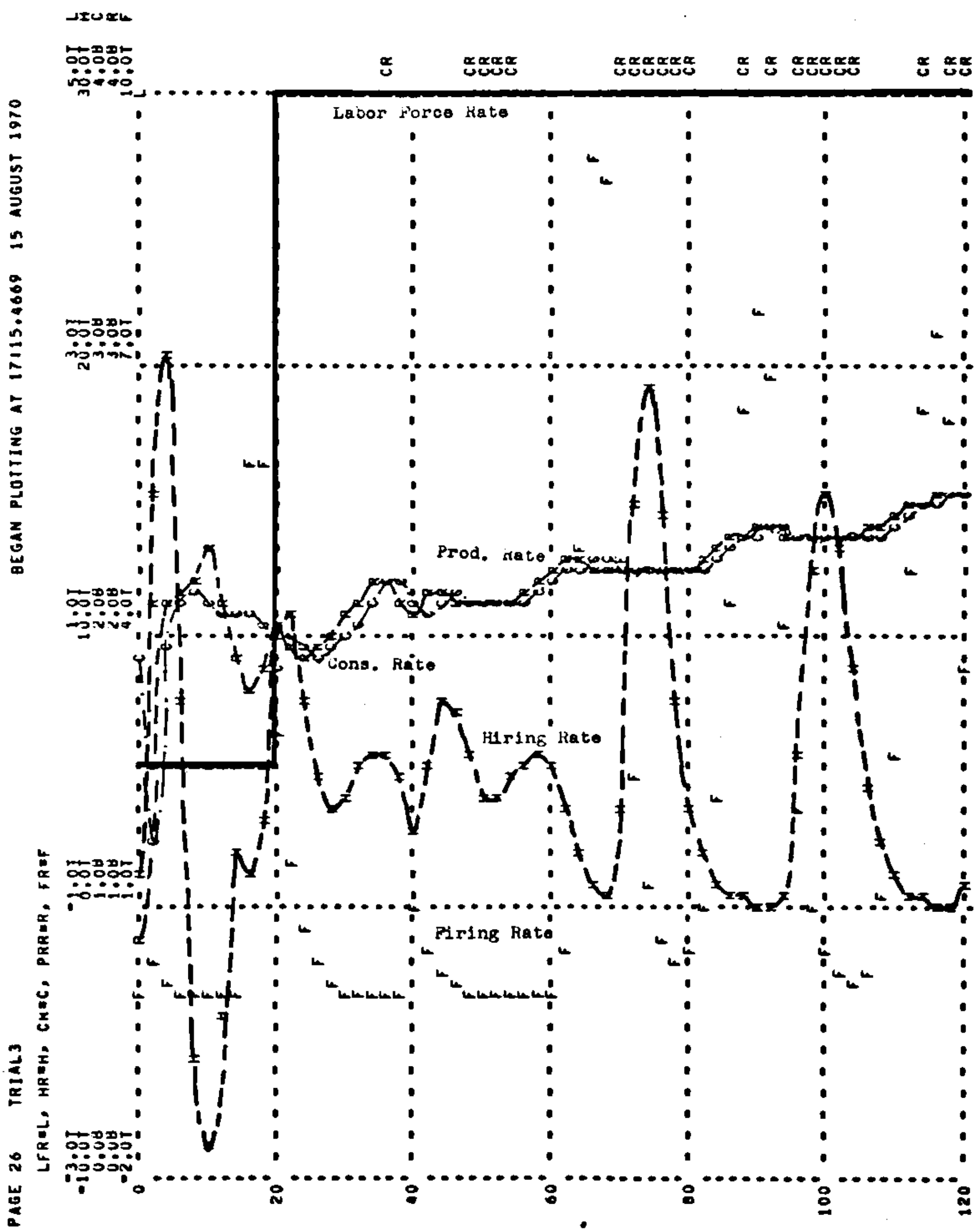


Fig. 30. Behavior of the Model Under a Step Increase in the Labor Force Rate

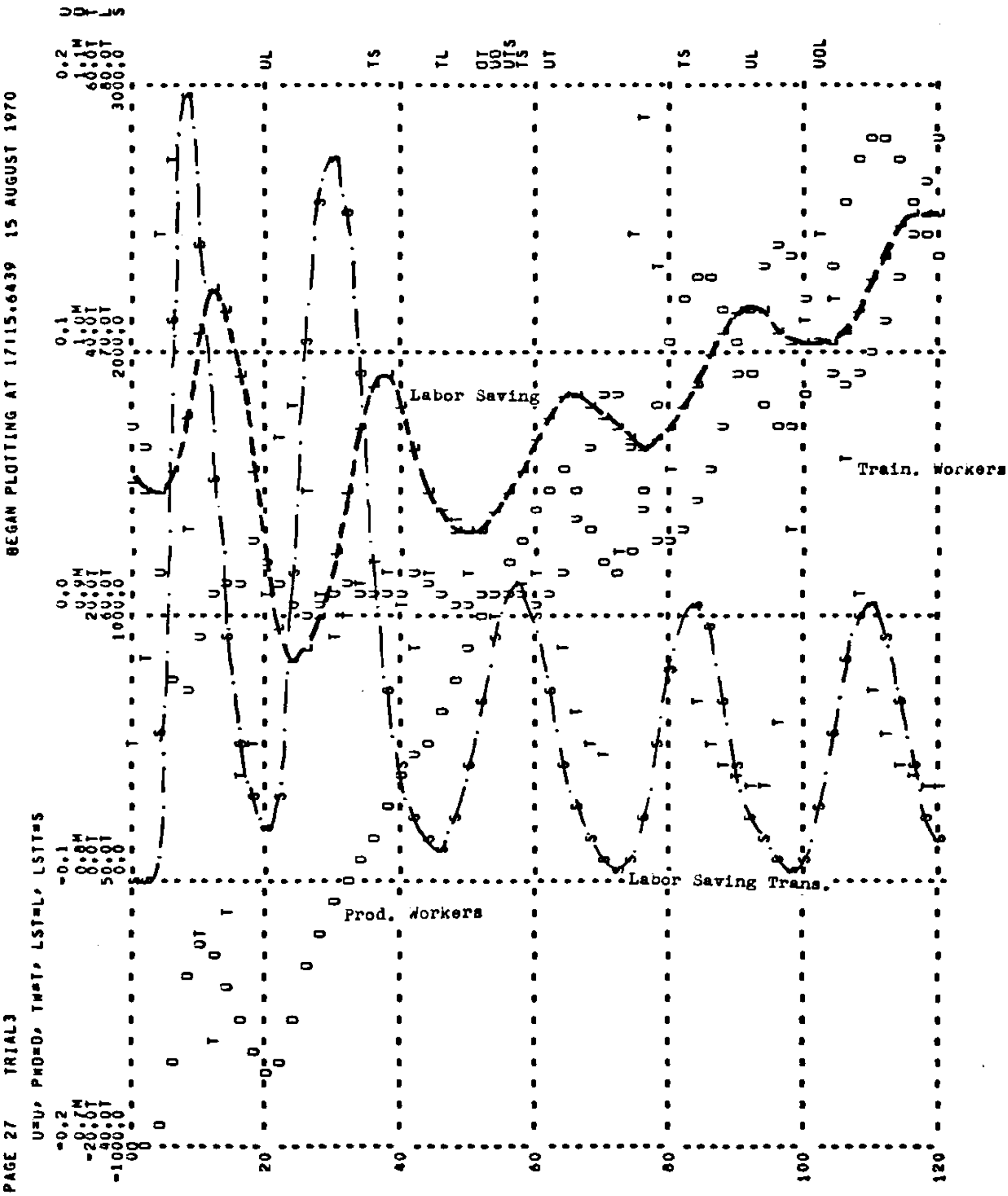


Fig. 31. Behavior of the Model Under a Step Increase in the Labor Force Rate

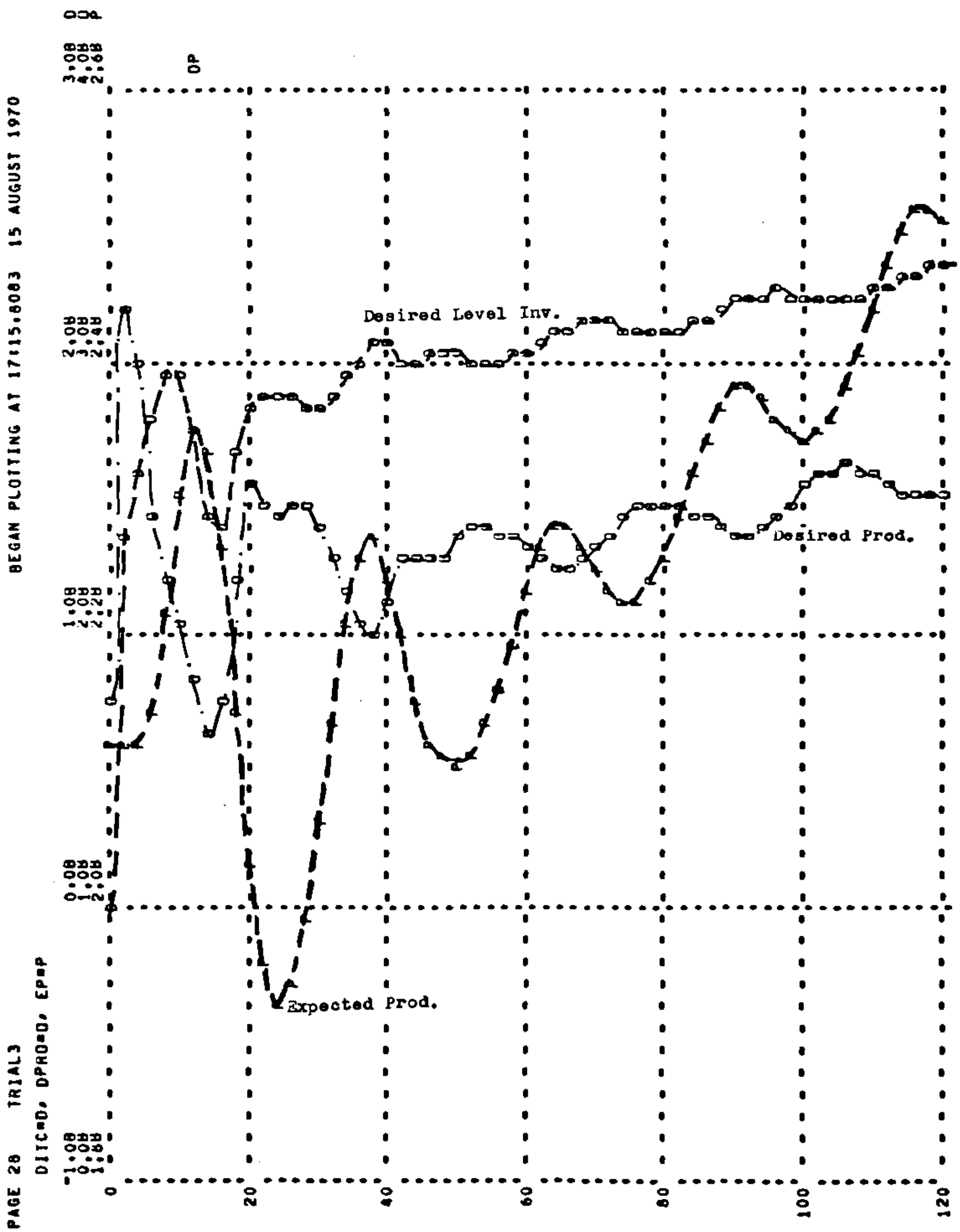


Fig. 32. Behavior of the Model Under a Step Increase in the Labor Force Rate

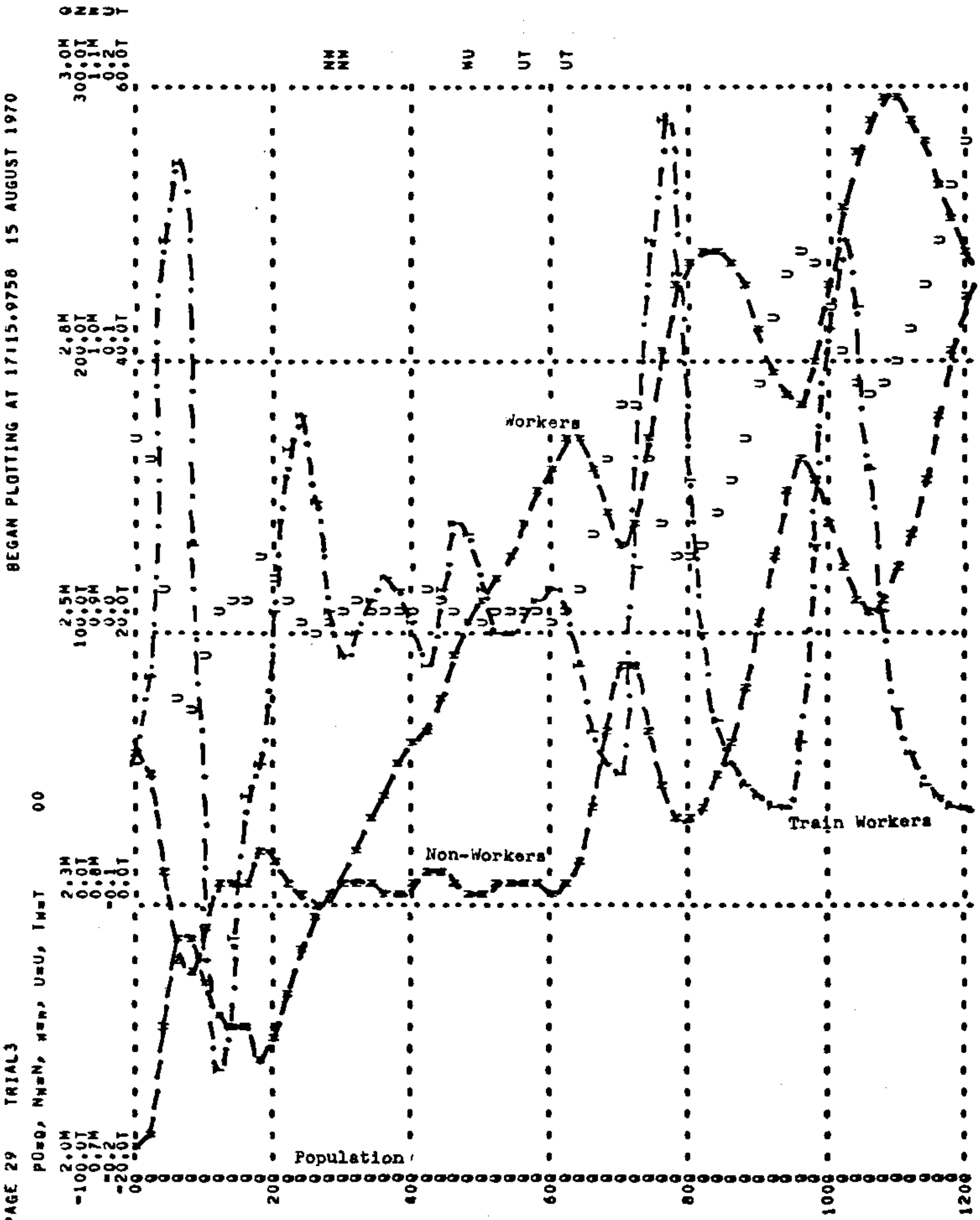


Fig. 33. Behavior of the Model Under a Step Increase in the Labor Force Rate

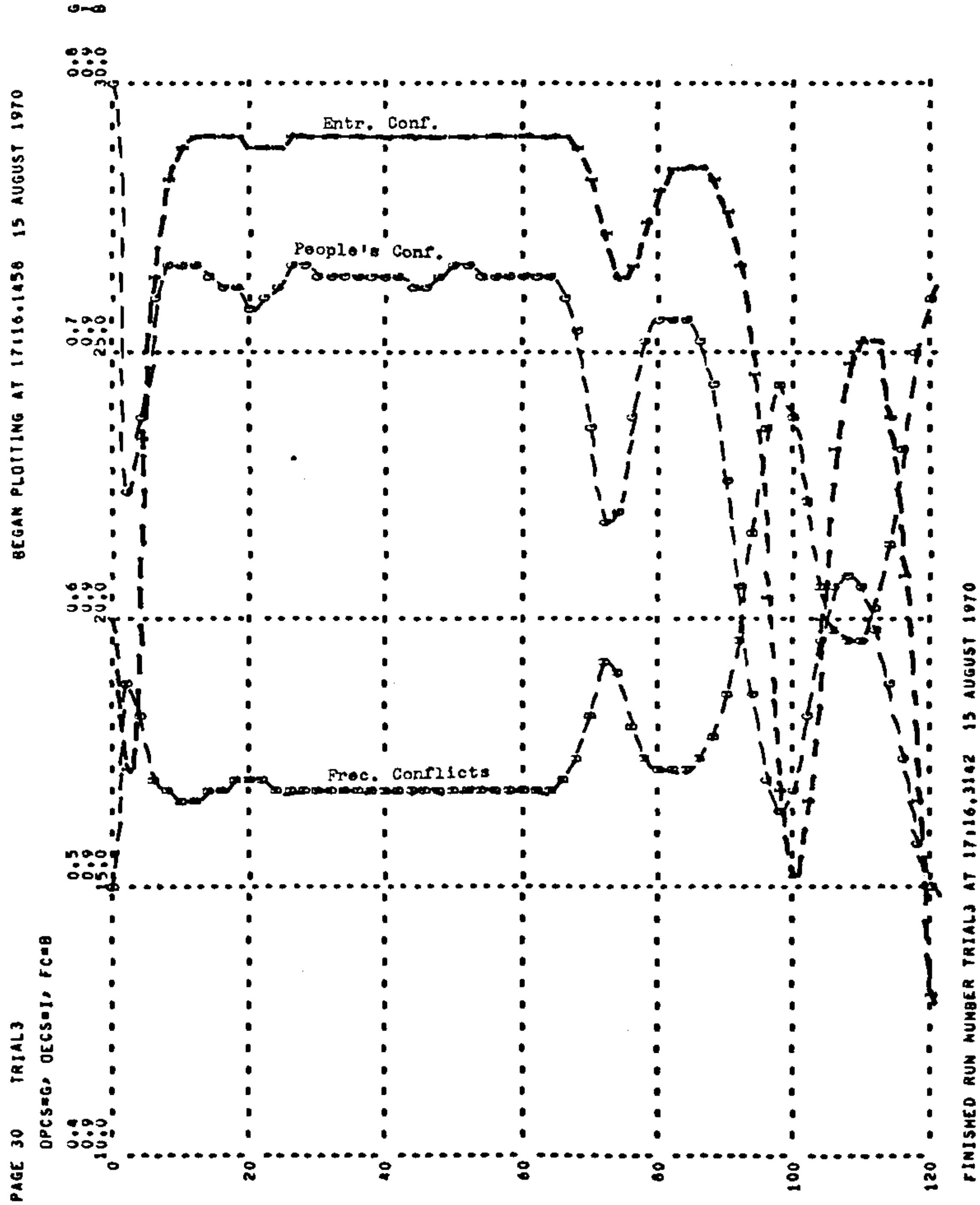


Fig. 34. Behavior of the Model Under a Step Increase in the Labor Force Rate

Table 13 shows the maximum values and the percentage of deviation of some of the variables. The time is counted after the labor force rate has been disturbed (20th month).

When unemployment shows a goal-seeking pattern (negative feedback), its natural period seems to be around 10 months. However, when it starts growing (and in unstable oscillation), the natural period is near 24 months. This could mean that at least one of the secondary negative feedbacks has become a predominant negative feedback and has imposed a new period of oscillation. A similar argument holds for the worker and non-worker levels.

The two different kinds of behavior exhibited by the patterns shown are caused by a change in the internal character of some of the information feedback loops. One of the related loops which has made such a switch in behavior is the one labeled #2 in Figure 26. During the first 60 months, this loop behaves in the same way as in the first section of this chapter. Although the feedback itself is positive, it behaves negatively because its gain is less than one. During this period of time, the new value of the labor force rate has not dominated the hiring rate. Figure 29 proves this fact: the worker level is increasing, while the non-worker level is almost constant. Under these conditions, unemployment declines (as shown) to very low values. This fact greatly enhances the people's confidence in the system, which in turn, causes the entrepreneurs' confidence to increase. The situation encourages entrepreneurs to hire more people; the resulting additional increase in the worker level and the lack of increase in the non-worker level make the unemployment percentage drop even more.

Table 13. Attenuation and Amplification Factors for the Labor Sector

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Time (mos.) | 20 | 32 | 42 | 56 | 70 | 95 | 120 |
| Unemploy- | Value (peak) | 0.02 | 0.01 | 0.015 | 0.01 | 0.09 | 0.14 | 0.18 |
| ment (U) | % | 100 | 0 | 50 | 0 | 44 | 29 | 21 |
| | Pattern | | oscillating; stable | | | growth and unstable oscillation | | |
| | Time (mos.) | 20 | 40 | 60 | 64 | 83 | 106 | |
| Workers | Value (peak) | 750,000 | 850,000 | 960,000 | 970,000 | 1,040,000 | 1,100,000 | |
| (W) | % | 3 | 0 | 0 | 2.1 | 4 | 4.6 | |
| | Pattern | | growth | | growth and unstable oscillation | | | |
| | Time (mos.) | 20 | 34 | 44 | 54 | 70 | 95 | 120 |
| Non-Workers | Value (peak) | 15,000 | 8,000 | 10,000 | 8,000 | 90,000 | 160,000 | 215,000 |
| (NW) | % | 100 | 0 | 25 | 0 | 50 | 25 | 16 |
| | Pattern | | stable oscillation | | | growth and unstable oscillation | | |
| | Time (mos.) | 22 | 44 | 52 | 72 | 97 | 120 | |
| Job Supply | Value (peak) | 250,000 | 60,000 | 60,000 | 40,000 | 30,000 | 0 | |
| (JS) | % | 40 | 16 | 16 | (oscillation around zero) | | | |
| | Pattern | | decline and stable oscillation | | | | | |
| | Time (mos.) | 22 | 35 | 44 | 58 | 75 | 100 | |
| Hiring Rate | Value (peak) | 1,100 | 5,000 | 7,500 | 5,000 | 19,000 | 15,000 | |
| (HR) | % | | oscillation around zero | | | | | |
| | | | stable oscillation | | | stable oscillation | | |
| | Time (mos.) | 18 | 40 | 68 | 90 | 118 | | |
| Firing | Value (peak) | 6,000 | 1,000 | 9,000 | 8,000 | 7,800 | | |
| Rate (FR) | Pattern | stable oscillation | | stable oscillation | | | | |

However, there must be at least one counterbalancing force which maintains unemployment at almost a constant value. One of these loops deals with the firing rate (FR). Although the job supply factor is positive most of the time, it becomes negative during some periods of time (18 and 40 months). This condition activates the firing rate (Fig. 30), which finally feeds the non-worker level and tends to increase unemployment, thus counterbalancing the previously decreasing unemployment. Finally, the negative feedback labeled 1 in Figure 26 also contributes to oscillation of unemployment during this 60-month period. As its character was explained in the previous section, it will not be repeated here.

After 60 months, the labor force rate makes its impact upon some feedbacks. The non-worker (NW) level begins to rise, and even though the number of workers also is increasing, unemployment begins to grow. At this time, the change of character of feedback #2 (Fig. 26) occurs. The increasing unemployment has a negative effect upon the people's confidence; the entrepreneurs' confidence starts decreasing (Fig. 34) and likewise the job supply, which now is oscillating around zero, but declining. This makes the non-worker and unemployment levels grow faster than they did before. The above chain of events also is illustrated in Figure 34, where the two confidence factors are seen to definitely change their behavior by the 60th month.

There are other interesting facts dealing with the hiring rate. During the first 60 months, the job supply is so high that entrepreneurs are able to hire "only" some small fraction of the workers desired (feedback NW - HR - NW, Fig. 26). However, after the 60th month, more non-workers are available and they can hire as many as they like. This cancels out the above feedback and allows others to be active.

The feedbacks dealing with the nominal salary, the consumption and production rates, and the labor-saving techniques do not show apparent changes with respect to their behavior in the previous section. However, the inventory level shows a difference that must be explained. Its pattern is one of growth as it was in the previous case, but it does not show any oscillation. However, comparison of Figures 23 and 32 reveals that the expected production (EP) is lower in the present case than it was in the first case. Furthermore, in Figure 23, EP was greater than the desired production (DPRO) by the 40th, 60th, 90th, and 110th months, while in the present case it is almost always less than DPRO. This fact is important, because the production rate (PRR) has been taken as the minimum between EP and DPRO. In case one, PRR was affected by feedback #1 (Fig. 26) or by others related to DPRO (#S.3 or 4, Fig. 27). This condition brought about periodic switching in the kind of feedbacks used. However, in case two, PRR depends almost exclusively upon feedback #1. This is one of the possible causes of the different pattern shown by the inventory curve.

## Behavior of the Model under a Step Increase in the Price Level

In this section the sensitivity of the model to a step increase in the price level is tested. Labor force rate and population patterns will be taken as growing exponential functions.

$$P.K = \begin{cases} 1, & TIME.K < 0 \\ 2, & \phantom{TIME.K} \geq 0 \end{cases}$$

P price level \$/unit

and

LFR.K = (SLF)EXP(RTL.K)

PO.K = (2E6)EXP(RT.K)

| | |
|---|---|
| LFR | Labor Force Rate (men/month) |
| PO | Population (men) |
| SLF | Initial Value (5000 men/month) |
| 2E6 | $2 \times 10^6$ men (initial value) |

and RTL and RT are the exponential rates for LFR and PO, respectively (Chapter V, Input Functions).

In order to show the influence of the price level increase on the model, two kinds of simulation runs are presented. Run A shows the behavior of the model when the labor force rate and the population are exponential functions, but the price level is maintained at a constant value of one dollar per unit (Figs. 35A-40A). On the other hand, run B shows the model's behavior under the same exponential functions, but with the price level maintained at two dollars per unit (Figs. 35B-40B).

As can be seen from the figures, the model is very sensitive to a 100 percent increase in the price level. While the model behaves as a somewhat growing process in run A, it shifts into a negative oscillatory character in run B. This also means that many (or at least one) of the feedback loops have changed from positive to negative.

A general idea of what could happen to the model will be given here. First, under an increase in price level, the consumption rate

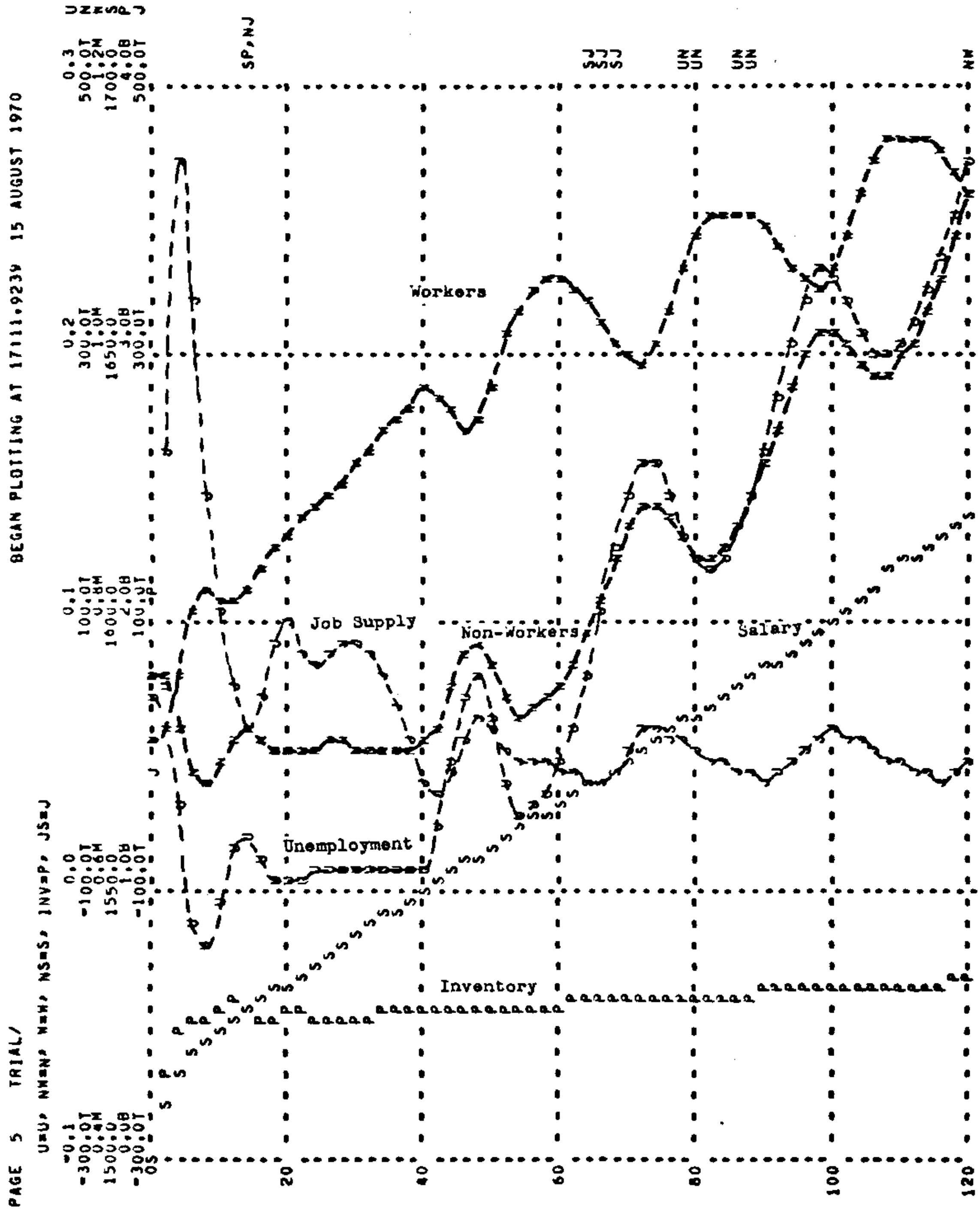


Fig. 35A. Behavior of the Model Under an Exponential Labor Force Rate and Price Level

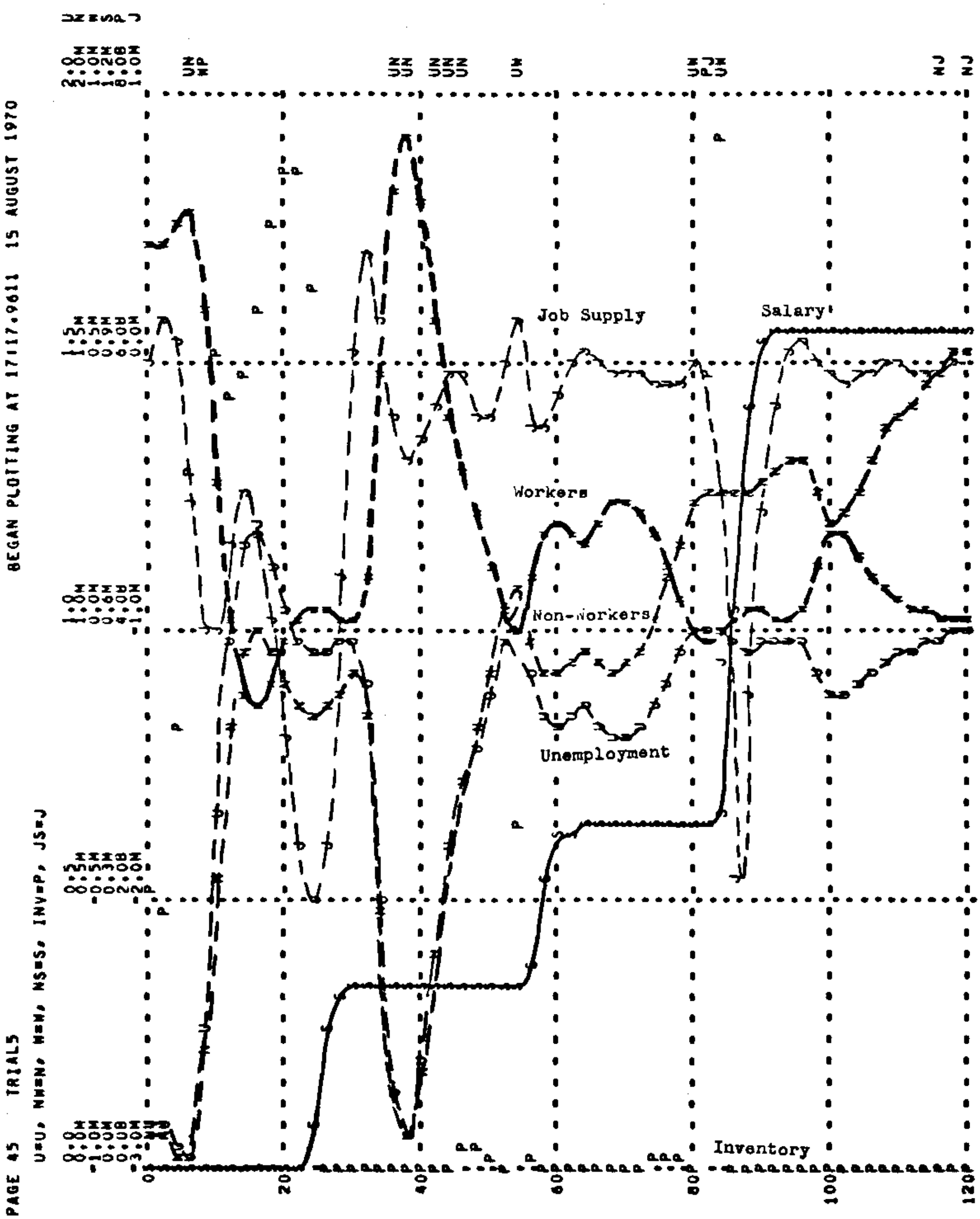


Fig. 35B. Behavior of the Model Under a Step Increase in the Price Level

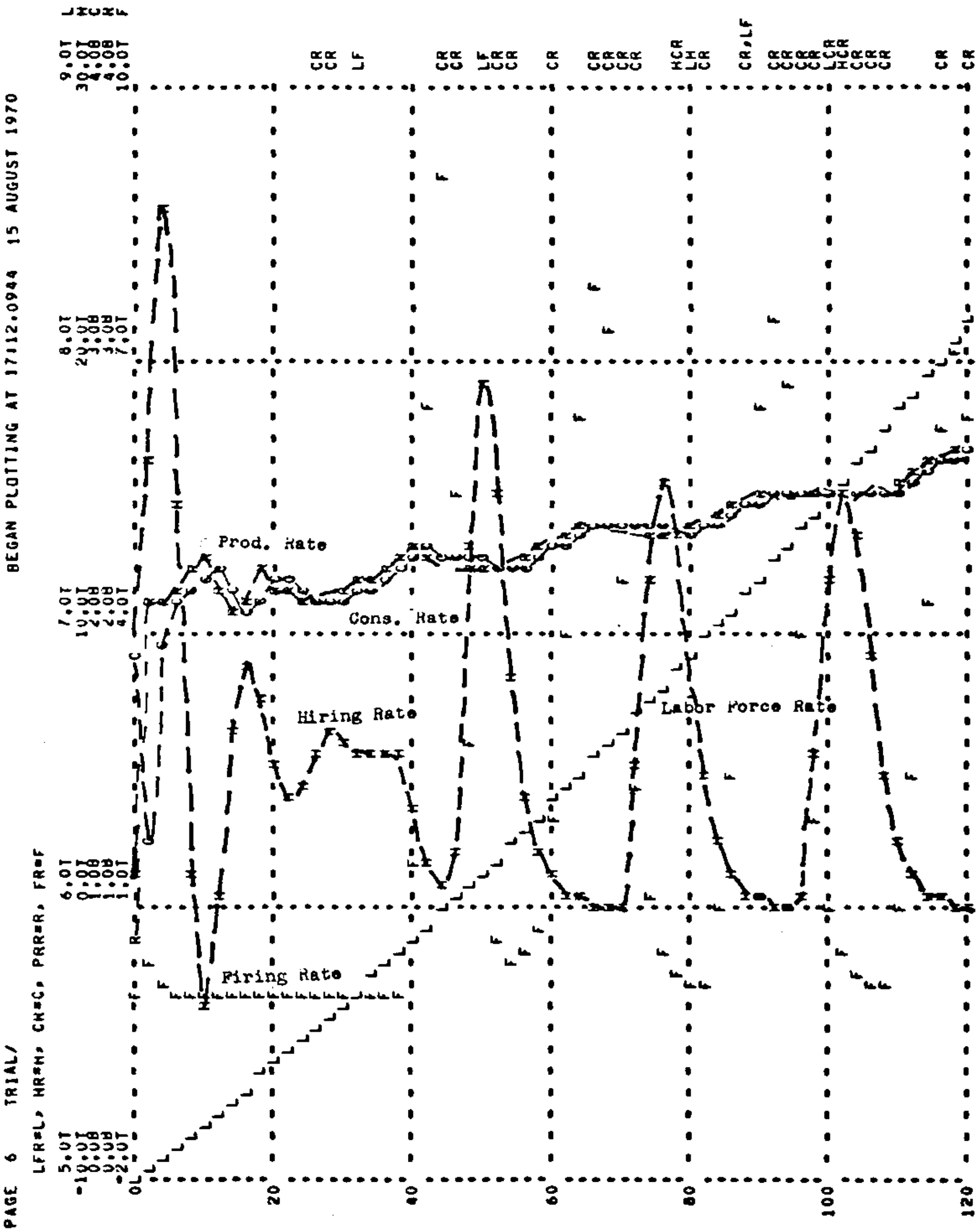


Fig. 36A. Behavior of the Model under an Exponential Labor Force Rate and Constant Price Level

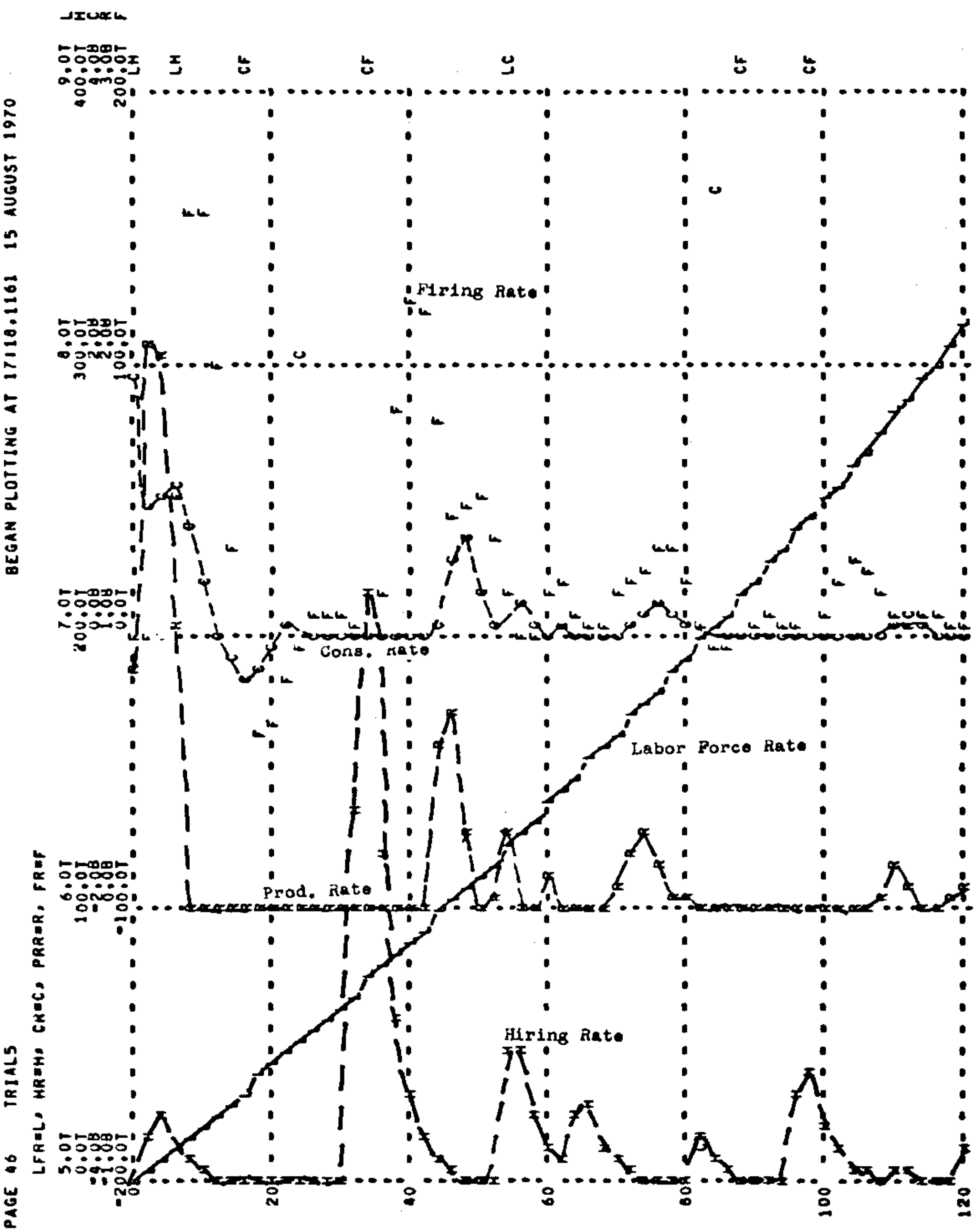


Fig. 36B. Behavior of the Model Under a Step Increase in the Price Level

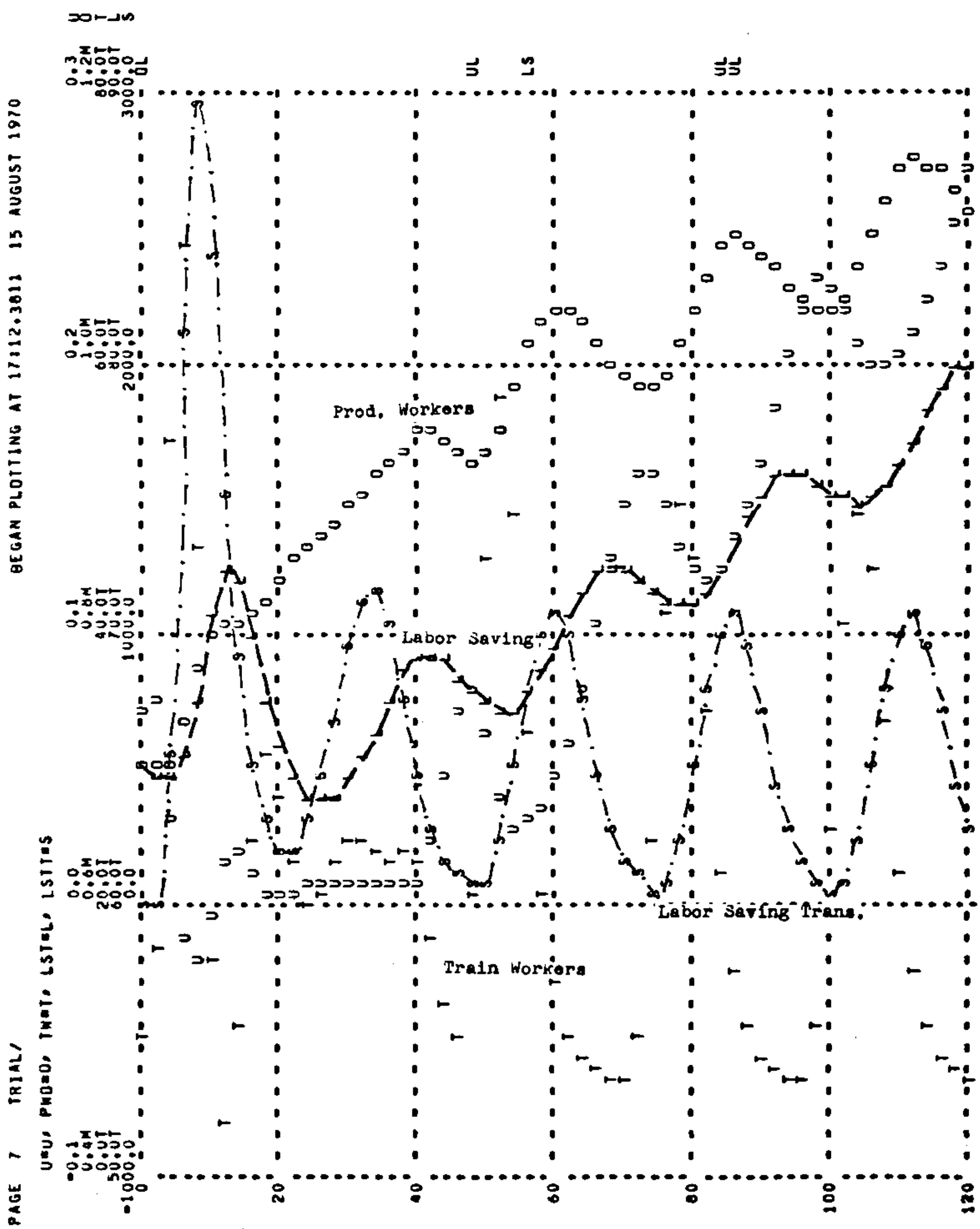


Fig. 37A. Behavior of the Model under an Exponential Labor Force Rate and Price Level Constant

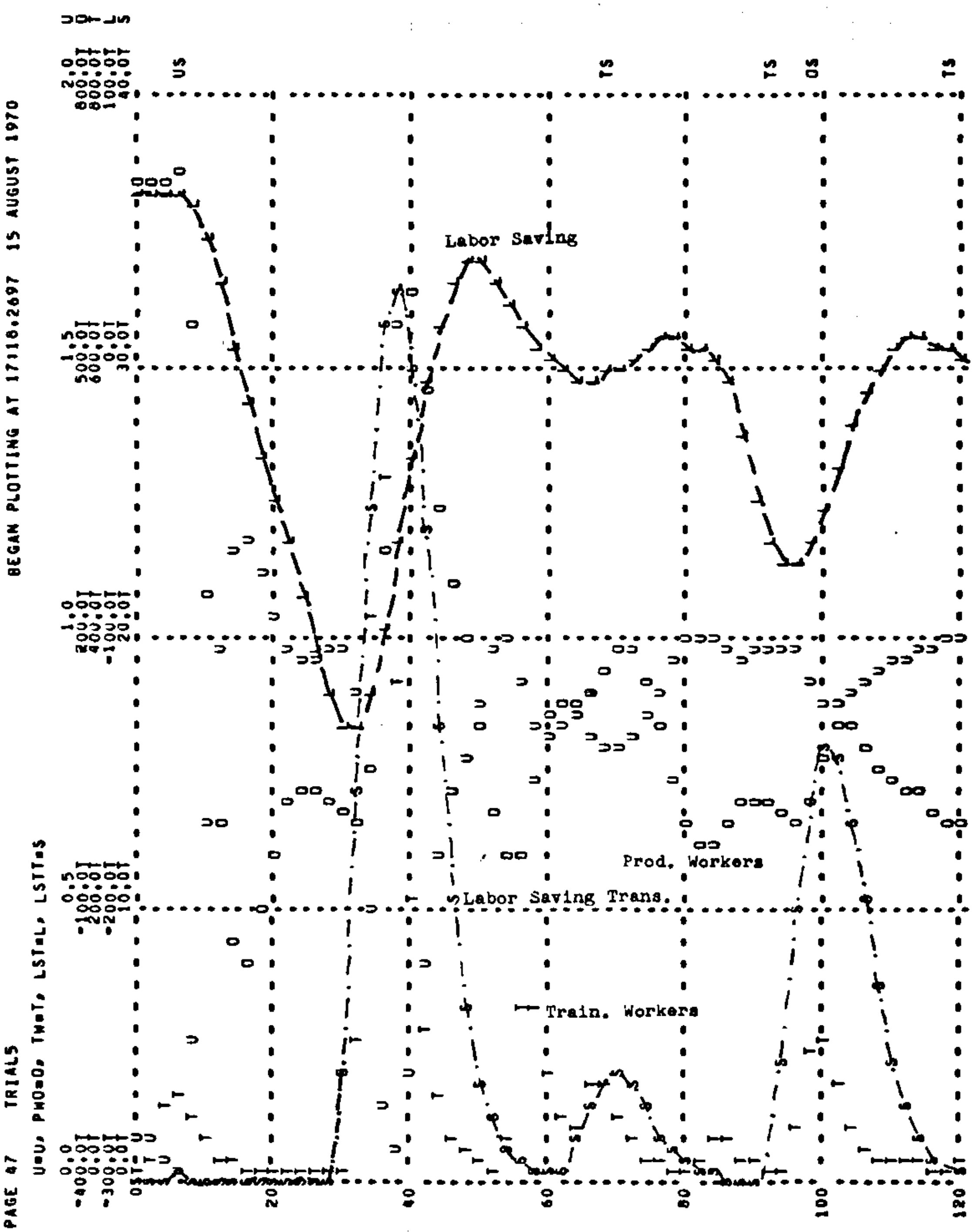


Fig. 37B. Behavior of the Model Under a Step Increase in the Price Level

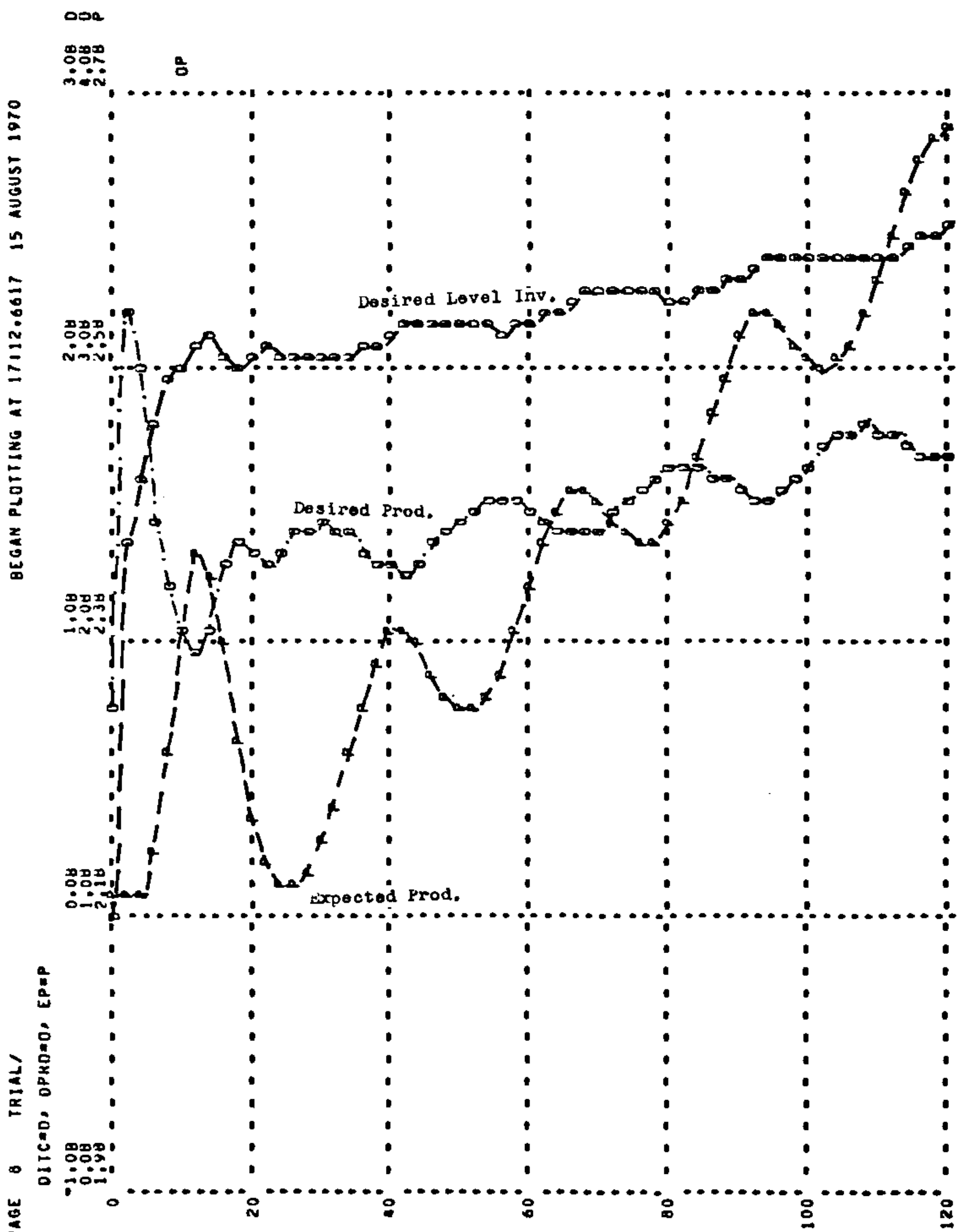


Fig. 38A. Behavior of the Model under an Exponential Labor Force Rate and Price Level Constant

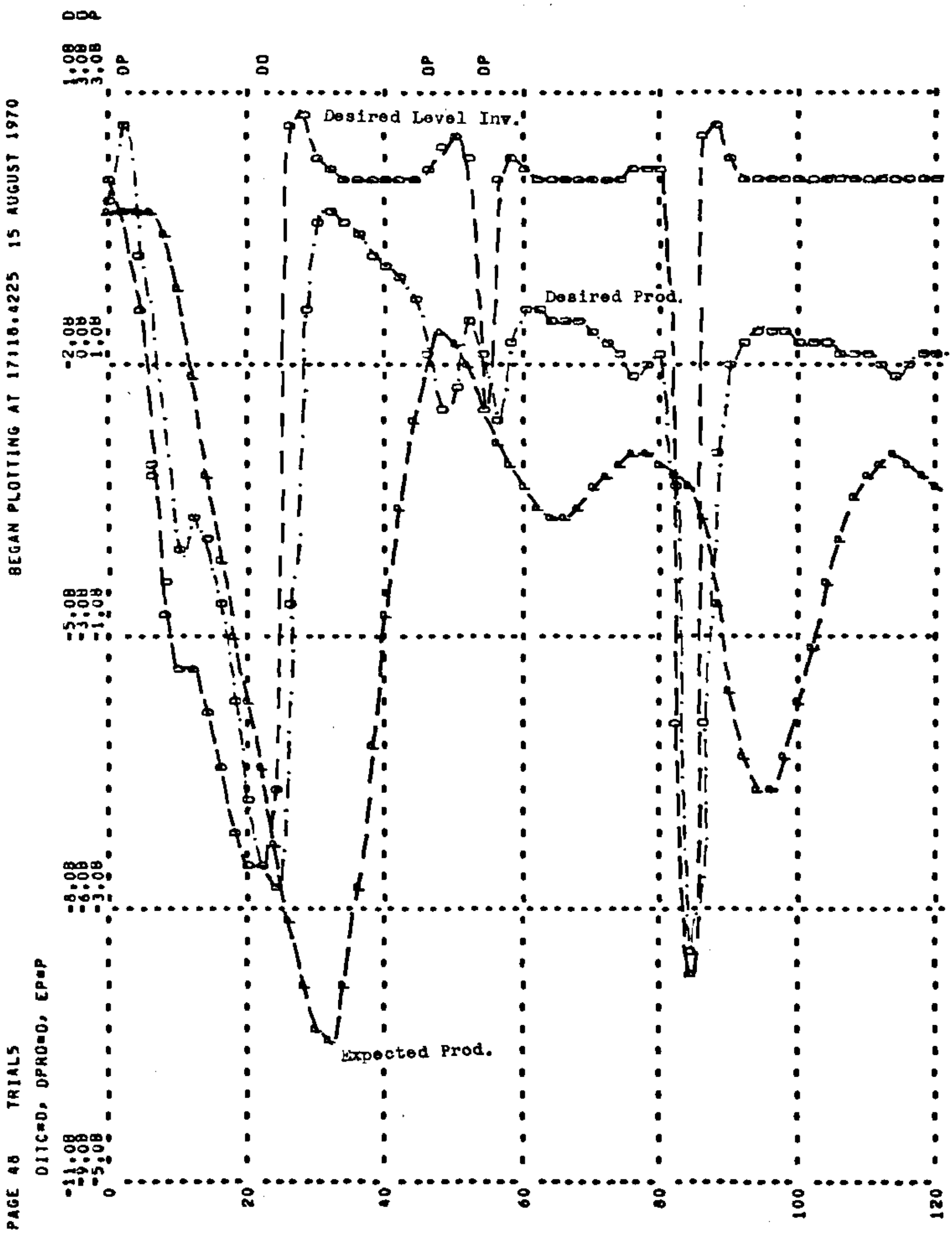


Fig. 38B. Behavior of the Model Under a Step Increase of the Price Level

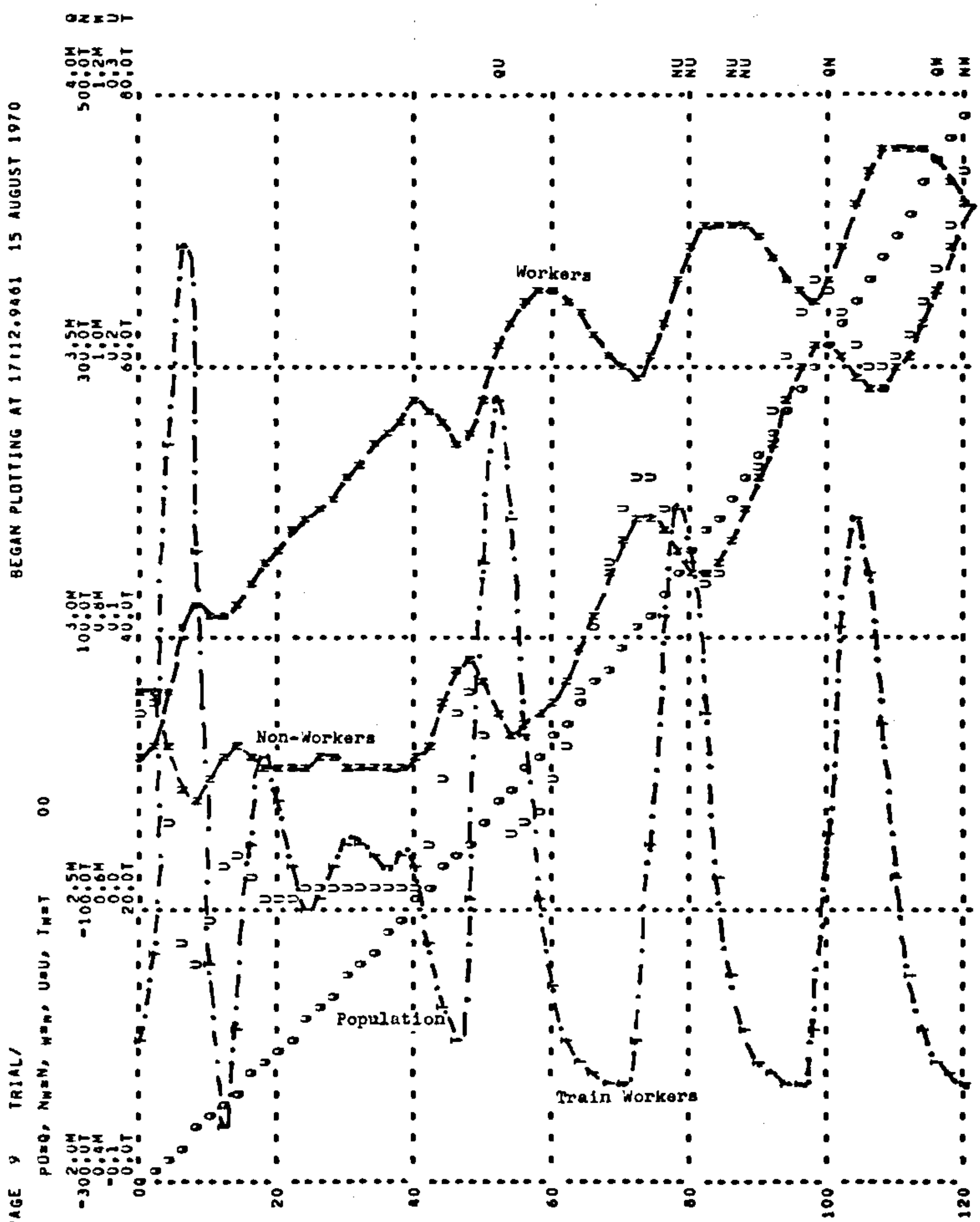


Fig. 39A. Behavior of the Model under an Exponential Labor Force Rate and Price Level Constant

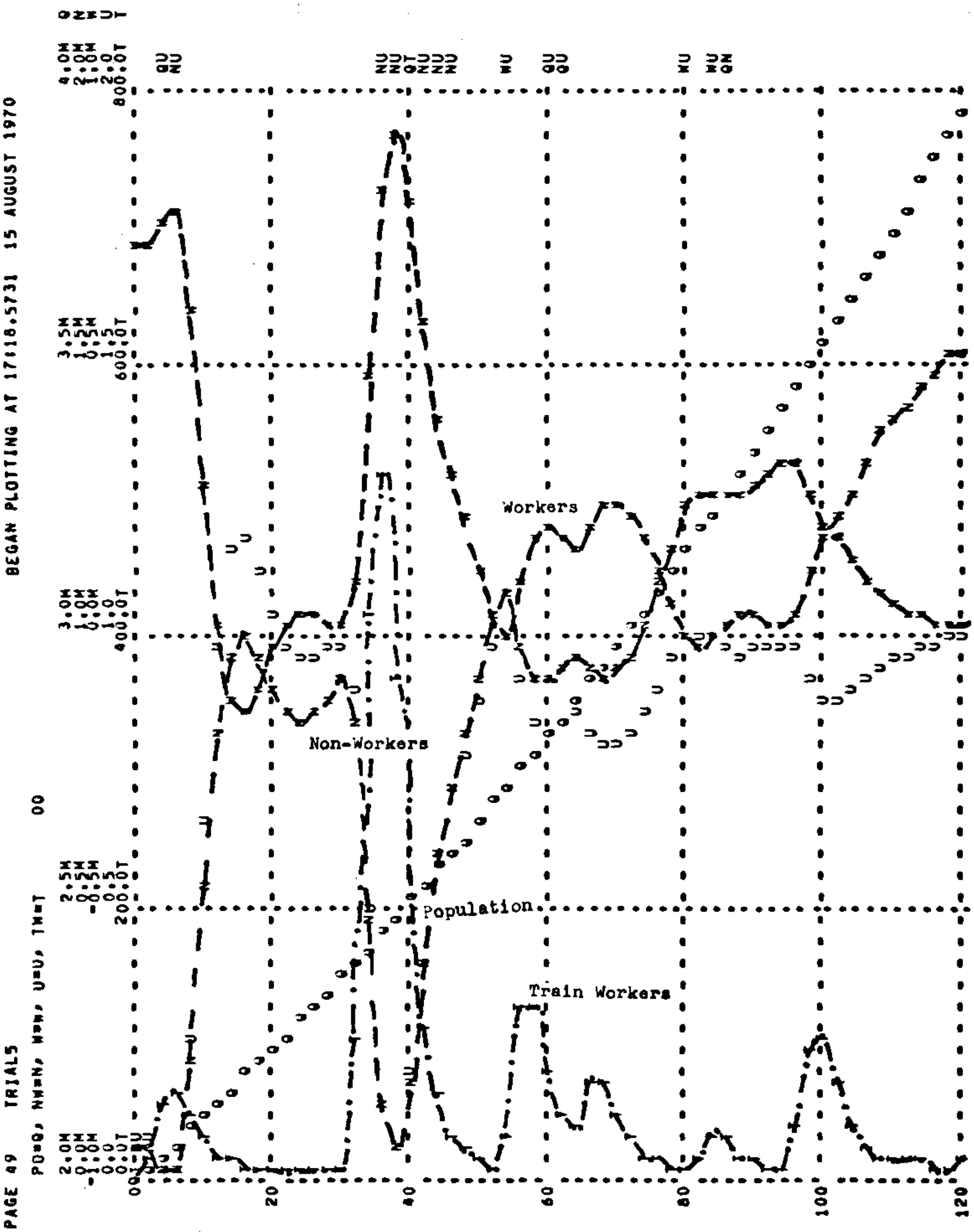


Fig. 39B. Behavior of the Model Under a Step Increase in the Price Level

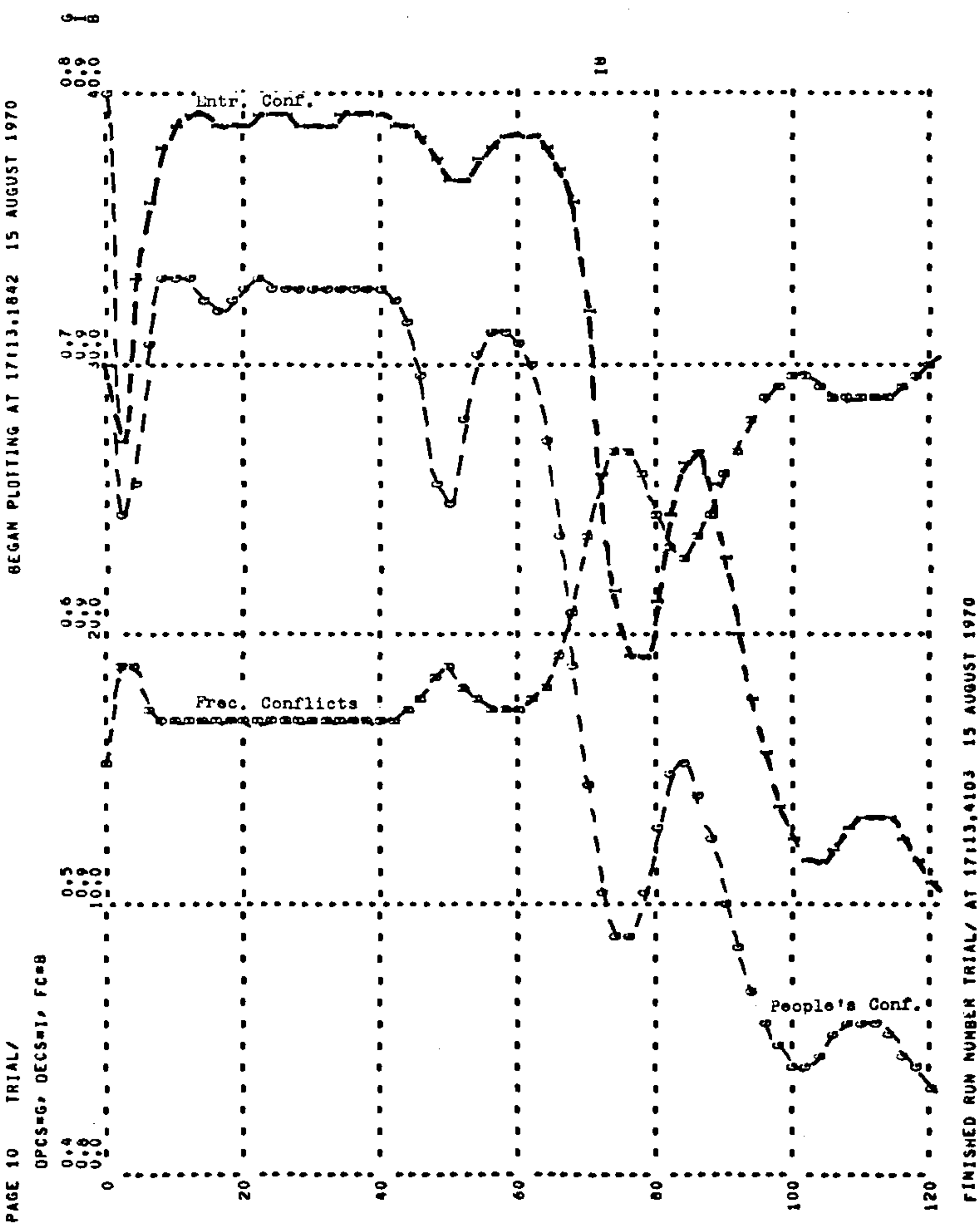


Fig. 40A. Behavior of the Model under an Exponential
Labor Force Rate and Price Level Constant

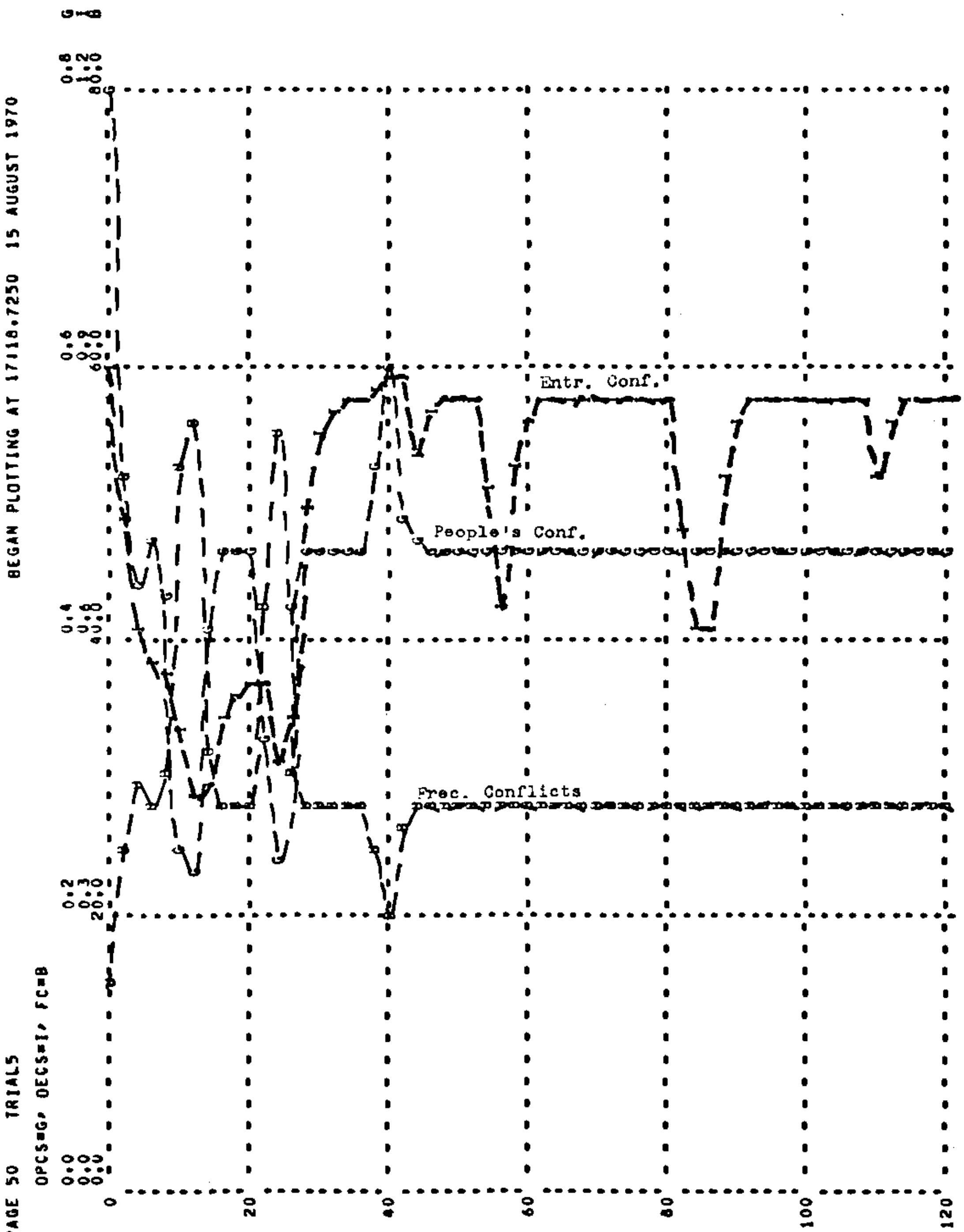


Fig. 40B. Behavior of the Model Under a Step Increase in the Price Level

becomes comparatively less than in run A (Figs. 36A, 36B). After some months, entrepreneurs observe their past sales (average consumption rate) and decide to order less production for the coming months. This fact reduces the desired production by workers (DPRW), which, in turn, reduces the job supply. The job supply reaches a very large negative value by the 24th month (Fig. 35B). By that time, unemployment has grown so much that the workers, having to support economically many of the unemployed (high dependence factor(DEP)), exert strong pressures upon salaries. A sudden increase in nominal salary (price level constant) again increases the consumption rate, which causes inventories to dwindle and finally has a positive affect upon the job supply (path #8-3, Fig. 26). This situation influences the hiring rate, which reaches a peak by the 30th month. The worker level also begins rising by this month (there is the delay for trainees) and reaches its peak by the 38th month. Unfortunately, the job supply will not increase forever. Once entrepreneurs have filled their required jobs, the worker level is so high that it surpasses the intended desires for new workers (IDWO, Fig. 26). Since the job supply is the difference between these two variables, it switches back to a negative value. Once again, the worker level decreases, and unemployment reaches values near 1.0.

Although the above cycle seems to be repeated each 24 months, the oscillation of the worker and unemployment curves shows some attenuation.

Some additional facts must be observed. First, the step increases in the nominal salary occur at the same periods of time that the worker level is reaching its peak value. Second, the jumps in the nominal salary occur simultaneously with a rather strong negative peak of the job supply. Third, when the nominal salary is in the step increase, the job supply oscillates around a negative value (Fig. 35B).

The negative value of the job supply persists during most of the computer run of the model. This fact, combined with the increasing labor force rate, causes the non-worker level to grow.

As the firing rate gains dominance over the hiring rate, the worker level approaches zero. Under this situation, the unemployment level must approach one.

# CHAPTER VII

# CONCLUSIONS AND RECOMMENDATIONS

## Conclusions

The previous chapter showed the behavior of the model under some selected input functions. In case two (labor force rate as step function) and in case three (price level step increase against labor force rate as an exponential function), the model behaved quite similarly to the expected behavior described in Chapter IV. However, the model itself presents so many weaknesses that we must conclude that it is a far from adequate representation of the real system. Some of the main pitfalls exhibited by the model are the following:

(a) The model does not make any distinction between the production of goods and the production of services. In developing countries, services are produced mainly by governments and generally lag the related production of goods. This situation introduces a time span between services and goods which can lead to strong changes in the character of the system.

(b) Those policies governing the labor sector do not totally represent the actual policies in the real system. The model assumes that the hiring rate (and the firing rate) cannot be less than zero, unless the non-workers also are less than zero (an unrealistic situation). This assumption means that entrepreneurs, when they must fire people, will prefer to fire some of their production workers rather than to fire some of their trainees.

(c) The people's and entrepreneurs' confidence factors are represented by smoothing, averaging equations. They belong to a channel of information. However, an information flow is entirely different from the other kinds of flows (goods, people, orders, money, capital goods). while the latter cannot be destroyed (they are conservative flows), the information flow can. This means that the confidence flow may be greatly changed (even destroyed) from one day to another. Evidently, this fact is absurd because the people's confidence is a subjective thing which cannot be immediately changed.

(d) Variables in the model do not influence the price level (an input function). This means that we have not been concerned about the important feedback loop existing between the production sector, the capital-goods sector, and the price level.

The following conclusions deal with the sensitivity of parameters, beginning values, and input functions. The model was actually run more than 150 times.

1. The model is not very sensitive to small changes in most of the parameter values. However, the model is sensitive to changes in the following parameters:

(a) PTUW = Propensity to Use Workers
(table function)

The sensitivity of this table function was found by making changes in the auxiliary variable PNPRW. For PNPRW $\geq$ 0.3, the model changed its behavior. (The actual value of PNPRW is 0.1.)

(b) The control factor (CF) is an auxiliary variable designed to test sensitivity of the fraction of inventories to control (FITC, a table function), which affects both the desired inventories and backlogs to control per month. The actual value of CF is 0.3. If CF is taken $\geq$ 0.6, the model changes its behavior.

2. Many runs were made for different values of the jump for the step increase in the labor force rate input. Within a range of 1000 to 7000 men per month, the model behaved in the same way.

3. Non-sensitivity also was found for changes in the rate of increase of population (and labor force). The range was checked for some values between: 4.8%, 6.7%.

4. When the model exhibited growth behavior, it was very sensitive to the beginning values. This characteristic is not uncommon in unstable growing processes.

5. The model is highly sensitive to the price level. When the price level was increased, unemployment reached very high values. In fact, a change of 100 percent in the price leads to a final unemployment of 1.0, which represents an increase near 1000 percent. This means that a percentage increase in prices leads to an even greater change in unemployment. This fact does not agree with the pattern expected by economists in most cities. They have observed an inverse relationship between percentage changes in the price level and unemployment (Phillips curve, 3, p. 28; 25).

## Recommendations

1. The model must be reviewed and redesigned. All policies must be redefined in order to make the model more realistic.

2. Special attention must be given to the confidence sector. It must represent a network of a conservative flow of confidence units, with its levels and decisions interconnected by the information network to other sectors of the system.

3. The price level must be included within the model. It must interact with the production and consumption sector, and also with the labor-savings techniques sector.

4. Once the new model is redesigned, tested, and proved to represent the real system, the next step must be to select appropriate targets for improvement and to define new policies which will generate those improvements.

The final recommendation deals with industrial dynamics methodology:

5. The feedbacks shown in Figures 26, 27, and 28 represent a signal flow graph. When taking the sensitivity of parameters, it may be helpful to find out those parameters which belong to some non-touching loops (one, two, three, etc., at a time). In such case, it may be useful to use any algorithm which facilitates selection of those non-touching loops. A newly revised version of the DYNAMO language allows the simulation run to be stopped and any kind of subroutine to be used.

# CHAPTER VIII

## SUMMARY

The simulation in this study has been a first attempt to use industrial dynamics philosophy and methodology to represent the dynamics of unemployment in a developing city. It does not pretend in any way to offer definite conclusions concerning the unemployment problem, and even less to give appropriate solutions. Rather, it tries to explain how industrial dynamics can be used in the study of this kind of complex system.

APPENDIX

```
?COMPILE BIN0290/ANALYSS*DYNAMO          ,0513800012  *0290 SERNA R
?PROCESS=  15;IU=   5,
?DATA,
?
?

                     UNEMPLOIMENT ANALYSIS FOR BOGOTA
      RUN    TRIAL/
                          WORKERS SECTOR
      52L    NW.K=NW.J+(DT)(LFR.JK+FR.JK-HR.JK+0)
      1L     TW.K=TW.J+(DT)(HR.JK-TWR.JK)
      39R    TWR.KL=DELAY3(HR.JK,DTR)
      12A    NWRH.K=(PNRH)(NW.K)
      56A    HW.K=MAX(0,JS.K)
      54A    PNH.K=MIN(HW.K,NWRH.K)
      3L     IHNW.K=IHNW.J+(DT)(1/DHN)(PNH.J-IHNW.J)
      20R    HR.KL=IHNW.K/DFJ
      1L     PWO.K=PWO.J+(DT)(TWR.JK-FR.JK)
      8A     JS.K=LDWO.K-TW.K-PWO.K
      56A    FW.K=MAX(0,-JS.K)
      12A    WRF.K=(PWRF)(PWO.K)
      54A    PWF.K=MIN(FW.K,WRF.K)
      3L     IFW.K=IFW.J+(DT)(1/DFW)(PWF.J-IFW.J)
      20R    FR.KL=IFW.K/DFR
      7A     W.K=TW.K+PWO.K
      48A    U.K=NW.K/(NW.K+W.K)                                              4A
      3L     OU.K=OU.J+(DT)(1/DOU)(U.J-OU.J)                                  5L
                          SALARY SECTOR
      12A    VA1.K=(2)(OU.K)                                                  6A
      26A    FU.K=(1-VA1.K+0)/(1-OU.K+0)                                      7A
      12A    TCW.K=(W.K)(NS.K)                                                13A
      42A    PCW.K=TCW.K/((P.K)(ACR.K))                                       14A
      7A     P.K=PRAM.K+PSIN.K
      58A    MPIS.K=TABHL(TPIS,PCW.K,0,1,0.1)                                 15A
      13A    ASOE.K=(FU.K)(MPIS.K)(NS.K)                                      16A
      12A    ESOE.K=(ASOE.K)(AFS)
      20A    DEP.K=PO.K/W.K
      12A    RLC.K=(LC)(P.K)
      20A    DAMP.K=ESCO.K/DEP.K
      7A     DESL.K=RLC.K-DAMP.K
      50A    AV2.K=(DEP.K)(DESL.K)/(NS.K+0)
      7A     PIS.K=AV2.K-1                                                    19A
      3L     APIS.K=APIS.J+(DT)(1/DAP)(PIS.J-APIS.J)                          20L
      58A    VDIS.K=TABHL(TDIS,APIS.K,0,1,0.1)                                21A
      1L     NS.K=NS.J+(DT)(ESR.JK-0)
      39R    ESR.KL=DELAY3(NSR.JK,DEFS)
      1L     ESCO.K=ESCO.J+(DT)(NSR.JK-ESR.JK)
      20A    ANSR.K=ESOE.K/VDIS.K
      56R    NSR.KL=MAX(0,ANSR.K)
      12A    ENS.K=(PCO)(NS.K)
      20A    ERS.K=ENS.K/P.K                                                  29A
                          PRODUCTION SECTOR
      13A    PCR.K=(CEXPF)(ERS.K)(W.K)
      20A    MCR.K=INV.K/OCI
      16     INV.K=INV.J+(DT)(IR.JK-CR.JK)
      1L     GIP.K=GIP.J+(DT)(PRR.JK-IR.JK)
      39R    IR.KL=DELAY3(PRR.JK,DIR)
      12A    WE.K=(UFW)(PWO.K)
      12A    LE.K=(UFL)(LST.K)
      12A    PW.K=(APPW)(WE.K)                                                34A
      12A    PLS.K=(APLS)(LE.K)
      7A     EP.K=PW.K+PLS.K                                                  36A
      3L     ODPR.K=ODPR.J+(DT)(1/DODP)(DPRO.J-ODPR.J)
      54A    IPRR.K=MIN(ODPR.K,EP.K)
      56R    PRR.KL=MAX(IPRR.K,0)
      54R    CR.KL=MIN(MCR.K,PCR.K)
      3L     ACR.K=ACR.J+(DT)(1/DDAC)(CR.JK-ACR.J)                            38L
      3L     DI.K=DI.J+(DT)(1/DDI)(INV.J-DI.J)
      12A    DLI.K=(PDI)(ACR.K)
      7A     DITC.K=DLI.K-DI.K
      44A    DITCM.K=(DITC.K)(CF)/FITC.K
      58A    FITC.K=TABHL(IFITC,DECS.K,0,1,0.2)
      1L     BOR.K=BOR.J+(DT)(OR.JK-IR.JK)
      12A    DLO.K=(PDB)(ACR.K)
      7A     DBTC.K=DLO.K-BOR.K
      44A    DBTCM.K=(DBTC.K)(CF)/FITC.K
      8R     OR.KL=ACR.K+DITCM.K+DBTCM.K
      6A     DPRO.K=BOR.K
      13A    DPRW.K=(PNPRW)(DPRO.K)(PTUW.K)
      7A     DPLS.K=DPRO.K-DPRW.K
                          CAPITAL SAVING TECHNIQUES SECTOR
      20A    DELS.K=DPLS.K/APLS
      3L     LDLS.K=LDLS.J+(DT)(1/DLDL)(DELS.J-LDLS.J)
      1L     LSTT.K=LSTT.J+(DT)(LSTR.JK-LSTR.JK)
```

```
39R    LSTR.KL=DELAY3(LSIR.JK,DLT)
1L     LST.K=LST.J+(DT)(LSIR.JK-LSUR.JK)
8A     TLSN.K=LDLS.K-LST.K-LSTT.K
56A    NLS.K=MAX(0,TLSN.K)
56A    DLS.K=MAX(0,-TLSN.K)
3L     INLS.K=INLS.J+(DT)(1/DILS)(NLS.J-INLS.J)
20R    LSIR.KL=INLS.K/DLSI
3L     IDLS.K=IDLS.J+(DT)(1/DDLS)(DLS.J-IDLS.J)
20R    LSUR.KL=IDLS.K/DLSO
                    JOB SUPPLY SECTOR
20A    DWOR.K=DPRW.K/APPW
3L     LDWO.K=LDWO.J+(DT)(1/DLDW)(DWOR.J-LDWO.J)
                    PEOPLE AND ENTREPRENEUR,S CONFIDENCES
58A    UPCS.K=TABHL(TUPC,DU.K,0,0.25,0.05)
20A    CPC.K=ACR.K/PU.K
58A    CEPC.K=TABHL(TCEP,CPC.K,2700,3200,100)
58A    WPC.K=TABHL(TWPC,APIS.K,0,1,0.2)
26A    PCS.K=(UPCS.K+CEPC.K+WPC.K)/(WPCS+0+0)
3L     OPCS.K=OPCS.J+(DT)(1/DOPC)(PCS.J-OPCS.J)                 12L
58A    FC.K=TABHL(TAFC,OPCS.K,0,1,0.2)
20A    RSF.K=ACR.K/OI.K
58A    ECS1.K=TABHL(TEC1,FC.K,0,100,20)
58A    ECS2.K=TABHL(TEC2,RSF.K,0.8,0.925,0.025)
26A    ECS.K=(ECS1.K+ECS2.K+0)/(WECS+0+0)
3L     OECS.K=OECS.J+(DT)(1/DOEC)(ECS.J-OECS.J)                 50L
58A    PTUW.K=TABHL(TPTU,OECS.K,0,1,0.2)

       INITIAL CONDITIONS

6N     NW=56000
6N     TW=10000
6N     PW0=700000
6N     DU=0.08                                                  63N
6N     HR=1000
6N     NS=1500                                                  67N
6N     ESC0=100
6N     NSR=5
6N     LDW0=PW0
6N     LDLS=LST
6N     LSIR=0
6N     APIS=0.16                                                66N
6N     ACR=17.6E8
12N    OI=(PUI)(ACR)
6N     INV=OI
6N     DDPR=ACR
6N     BUR=ACR
6N     IMNW=0
6N     IFW=0
6N     LST=65E3
6N     LSTT=0
6N     IDLS=0
6N     INLS=0
20N    PRR=GIP/OIR
6N     GIP=ACR
6N     OPCS=0.8
6N     OECS=0.9

       PARAMETERS

C      DFJ=1
C      DFR=2
C      DIR=3
C      DHW=3
C      DFW=3
C      DUDP=3
C      LC=600
C      DAP=2
C      DUU=1                                                    82C
C      DLSI=6
C      DLSO=6
C      DILS=4
C      DDLS=4
C      DLT=2
C      APPW=300
C      APLS=30000
C      DUI=1
C      DUAC=2
C      DCI=0.25
C      CEXPF=2
C      P=1
C      DOPC=1
C      DOEC=2
C      PU=2E6                                                   104C
```

```
C       AFS=0.2
C       MPCS=300
C       MECS=200
C       DEFS=3
C       DIR=2
C       PNRH=0.8
C       PWRF=0.8
C       DLDW=2
C       DLDL=3
C       UFL=1
C       UFW=0.8
C       PUB=0.2
C       PUI=1.2
C       CF=0.3
C       PNPRW=0.1
C       PCD=0.9
        IMPUT FUNCTIONS
28A     LFR1.K=(SLF)EXP(RTL.K)
12A     LFR2.K=(TF)(JUMP.K)
45A     JUMP.K=STEP(JLF,20)
7R      LFR.KL=LFR1.K+LFR2.K
47A     PRAM.K=RAMP(RP,0)                                                    1061A
31A     PSIN.K=(MD)SIN((2PI)(TIME.K)/H)
28A     PU.K=(2E6)EXP(RT.K)                                                  1061A
12A     RT.K=(RATA)(TIME.K)                                                  1062A
44A     RTL.K=(RATA)(TIME.K)/GFLF
        IMPUT CONDITIONS
C       SLF=5000
C       RP=0
C       PRAM=1
C       MD=0
C       H=6
C       RATA=0.0057
C       GFLF=1.4
C       TF=0
C       JLF=5000
        TABLES FUNCTIONS
C       TPIS*=0.18/0.14/0.1/0.07/0.05/0.04/0.03/0.026/0.022/0.021/0.02       109C
C       TDIS*=10/7/5.2/4/3/2.4/1.8/1.5/1.3/1.2/1                             110C
C       TAFC*=100/60/32/20/15/10
C       TFIC*=2.2/2.8/3.2/3.5/4/4.8
C       TUPC*=100/90/60/32/24/20
C       TCEP*=20/40/58/84/96/100
C       TWPC*=100/90/76/44/28/20
C       TEC1*=100/90/70/40/24/20
C       TEC2*=30/40/60/80/92/100
C       TPTU*=0.75/0.95/1.05/1.15/1.25/1.5
PRINT   1)U/2)NW/3)W/4)NS/5)INV/6)NLS/7)LST/8)JS
PRINT   1)CR/2)PRR/3)HR/4)FR
PLOT    U=U/NW=N/W=W/NS=S/INV=P/JS=J
PLOT    LFR=L/HR=H/CR=C/PRR=R/FR=F
PLOT    U=U/PWD=D/TW=T/LSI=L/LSTT=S
PLOT    DITC=D/DPRD=O/EP=P
PLOT    PU=W/NW=N/W=W/U=U/TW=T
PLOT    OPCS=G/OECS=I/FC=H
SPEC    DT=0.25/LENGTH=120/PRTPER=2/PLTPER=2
RUN     TRIAL2
C       RATA=0
C       SLF=0
RUN     TRIAL3
C       TF=1
C       SLF=0
C       RATA=0
RUN     TRIAL4
C       TF=1
C       SLF=0
RUN     TRIAL5
C       PRAM=2
C       P=2
RUN     TRIAL6
C       CF=0.2
```

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